THE CANCER PROBLEM

A STATISTICAL STUDY

C. E. GREEN

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THE CANCER PROBLEM

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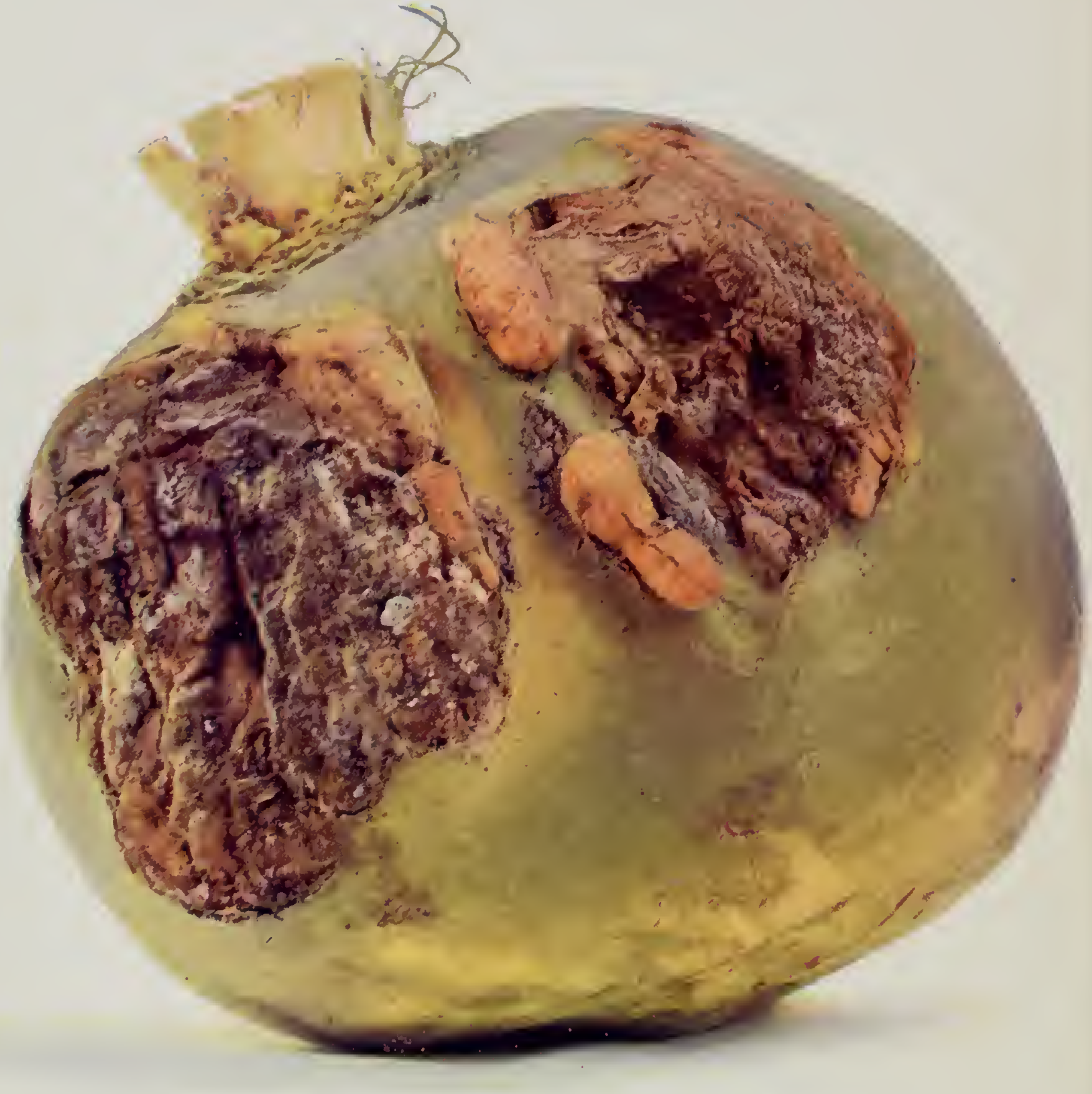

Ulcerating Tumours on the Bulb of a large Turnip due to a Minute Intracellular Parasite known as *Plasmodiophora brassicæ.* This is a phase of the disease known to agriculturists as finger-and-toe.

ontispiece.

THE CANCER PROBLEM

A STATISTICAL STUDY

BY

C. E. GREEN, F.R.S.E.

EUGENICS EDUCATION SOCIETY
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APOLOGIA

CITAVERIT vero aliquis notum illud "ne sutor ultra crepidam," scilicet prohibens indoctum medicinæ artem medicam tractare; tamen hunc reputare decet concedendum aliquid viro qui certum aliquod studium tanquam vitæ suæ metam amplexus postea autem impeditus ne vitæ cursum propositum sequeretur, propositum munus tantum *ἐν καίρω παρέργου* exercere fato cogitur.

CHAPTER I

THE CRUX OF THE PROBLEM

THE following pages are written in the hope that they may throw some light upon the sphinx-like riddle of malignant disease by the deductive method. Some years ago, after reading one of Dr. Conan Doyle's "Sherlock Holmes" stories, it occurred to me that if some of the world's great problems were attacked in a similar fashion good might result. As a former student of medicine the cancer problem at once occurred to my mind and in a very short time I was in the grip of an enthralling if somewhat gruesome hobby.

For the past five years I have endeavoured to collect every piece of evidence which seemed to bear upon the problem of malignant disease, in the hope that a clue might be got to the cause and possibly the cure of the condition.

Naturally, one first of all turned to the literature of the subject and to the latest teaching of pathology on the growth of neoplasms in all their varieties, clinical characteristics, and microscopic appearances. Histology seems to have said its last word on the subject, but it has done little to clear up the etiology, however valuable its processes are for purposes of diagnosis.

Hospital statistics have their value, but only prove that certain parts of the body are particularly liable to malignant disease. The statistics of the Registrar-General, however, seem to be in a different category, as they clearly prove—

(1) That cancer is much more prevalent in some districts than in others;

(2) That it is common in some trades and uncommon in others; and

(3) That these figures are fairly constant.

These three facts are surely of great significance. Why should the cancer death-rate be constantly higher in the case of chimney-sweeps than in the case of miners? Why should lawyers always be more liable to malignant disease than physicians, sailors than fishermen, furriers than tanners, lead-workers than copper-workers?

The local distribution is equally surprising.

In Scotland we get some very striking results.

To take the two extremes: in Nairn,[1] a beautiful county whose people are mainly engaged in pastoral pursuits, we find a cancer mortality of 9·73 per cent., while the city of Glasgow has only 2·98 per cent.

Viewed broadly, these curious facts raise at once a sharp issue which is not at first self-evident on the present theories of cancer origin.

The question at issue between these is whether cancer arises from a modification of the formative process, or is the result of stimulation by micro-organisms. In other words, is it of intrinsic or extrinsic origin? Now, if cancer be due to modifications of the formative cell processes, *why should these modifications always occur more frequently in some trades than in others, and be more prevalent in some districts than in others?* To say that sweeps or the natives of Nairnshire start life as a class with their cells particularly prone to these modifications is obviously absurd.

THESE STATISTICS PROVE THAT IT MUST BE SOME ELEMENT IN THE ENVIRONMENT OF THE SUFFERER WHICH INDUCES THE DISEASE, AND IF WE ADMIT THIS, WE MUST ADMIT AN EXTRINSIC ORIGIN.

Whatever it may be, and in whatever way it may act, some force outside the body *must* be at work, with the result that it sets up a strange condition of perpetual cell-growth which, pathologically, is a thing *per se*, and so far unaccountable. This force must of necessity be either mechanical, chemical, parasitic, or a subtle combination of the three.

---

[1] For full details regarding Nairnshire see chapter on Local Incidence.

Mechanical irritation is a commonly accepted factor in the etiology, but it is not a satisfactory one. It may have, like trauma generally, a predisposing effect, but it is far from being invariably present, and it is difficult to understand what mechanical irritation can cause a sarcoma of the pituitary body or even a uterine carcinoma.

The longer one considers the question the stronger the presumption becomes that the cause is biochemical or parasitic. A purely chemical action, however, will hardly account for such phenomena of cancer as secondary deposits, if the application of the chemical be local, as in petroleum cancer.

The parasitic theory of origin is at present out of fashion, but after disbelieving it and reading much that has been said against it, it seems to be the only one which will satisfactorily account for the high degree of proliferative activity which is the essential characteristic of the cells of malignant tumours and the cause of all their special qualities. It is unquestionable that in the vegetable kingdom a similar condition is induced by minute intracellular parasites.

One instance may be shortly referred to, simply to show how the presence of such a parasite strangely stimulates the cells of tubers in a manner which exactly simulates cancer. It is known as warty disease of potatoes, and has only within the last few years made its appearance in England. At the time of writing very few cases have occurred in Scotland.

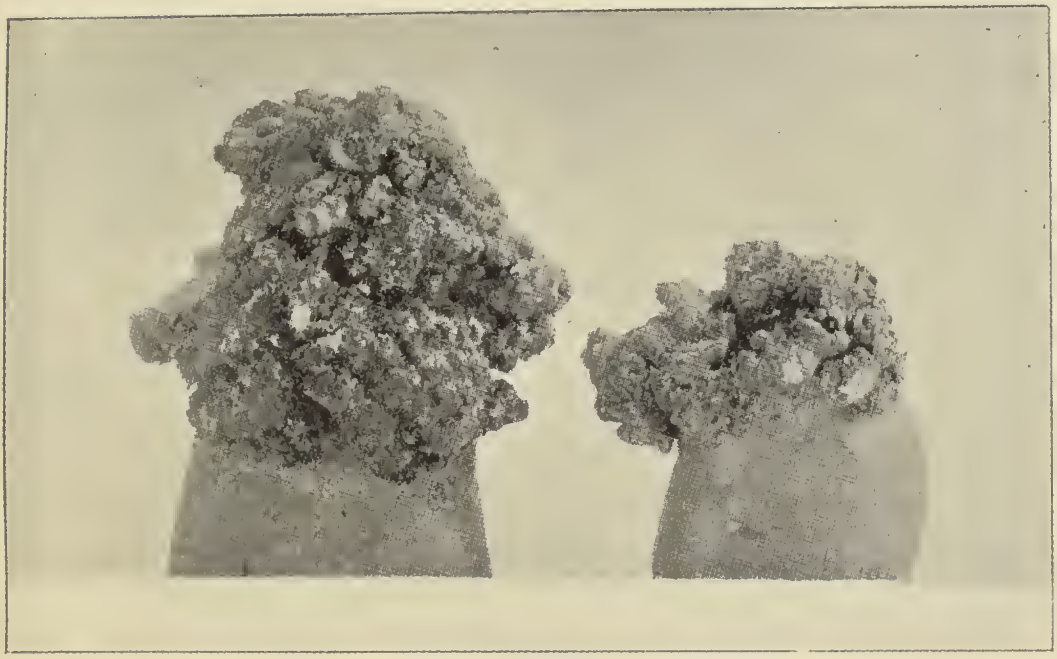

Fig. I.—Warty Disease in Potatoes.

In such plant diseases, and there are many, we have instances of the stimulation of protoplasm by other simple protoplasm in direct contact with it. Even this, however, is not necessary. Irritation and hypertrophy of cells may be caused, as Ward has shown, by parasites which never bring their protoplasm into direct contact with that of their host, but stimulate it through *both cell-walls* to abnormal growth. Not only are the cells stimulated to grow larger and divide oftener than normally, but the chlorophyll disappears, the cell-sap changes colour to red, the numerous compound crystals normally found in the tissues diminish in number and are different in shape, large quantities of starch are stored up, and even the vascular bundles are altered in character. All these changes indicate very profound alterations in the physiological working of the protoplasm of the cells of the host, and yet the parasite has done its work through both its own cell-walls and those of the host.

If, then, the presence of such organisms can set up so abnormal a growth in the case of vegetable cells, is it too much to account for the unlimited cell formation which is so puzzling in the case of cancer?

Although it may be said that there is a wide difference between the vegetable cell and the animal, and that a class of organism which causes the former to behave in this way may not similarly affect the animal cell, the fact remains that many of these plant parasites are communicable to, and cause the death of, insects. It must also be borne in mind that organisms such as those referred to are on the border line between plants and animals, and that not being considered pathogenic their very existence is almost unknown to pathologists.

In spite of the arguments of many pathologists one feels driven to these conclusions regarding cancer:—

(1) The occupational and local incidence point to an infection.

(2) This infection differs from any ordinary microbic one, in respect that—

  (*a*) It does not destroy the part, but stimulates it to enormous overgrowth.

  (*b*) It has no local inflammatory reaction and practically no fever.

(3) It has, on the other hand, a strong resemblance to animal diseases caused by micro-organisms, such as actinomycosis, which in cattle is often mistaken for cancer and scirrhus.

(4) Tumour growth in plants is, so far as known, invariably due to the presence of mycetozoan parasites, which it must be remembered are totally different from bacteria, fungi, and even protozoa.

(5) Cancerous tumours of mice, originating sporadically, have been subjected for twenty minutes to the extremely low temperature of −195° in liquid air, and yet inoculations of these produced new tumours. No animal cell could then retain its vitality, but the spores of such organisms could.

The analogy from these points seems too strong to be lightly set aside. I would go further, and say that a study of the life-history of certain organisms, which are on the border line between plants and animals, clears up much that seems obscure in the cancer problem.

The chief objections to the parasitic theory of cancer origin are well known. The cancer cell itself appears to act as a parasite, and the heterotype mitosis, which is characteristic of reproductive and germ cells, is also a feature in the multiplication of the cells of malignant tumours.

Sir Henry Butlin (*Brit. Med. Journ.*, 25th November 1911) tersely sums up the characteristics of the cancer cell as follows:—

> Cancer cells resemble those of the natural tissues in which the cancer appears to start.
>
> The secretion of cancer cells resembles the secretion of the natural cells.

The degenerations of the cells resemble those of the normal cells.

The grouping of the cells resembles the grouping of the natural cells.

The phenomena of reproduction in the cancer cells resemble those of the natural cells which they resemble.

In view of these facts it is obvious that if cancer be due to a parasite, it appears to be non-existent, and even if its existence could be proved it acts in a way in which no parasite known to medical science has ever acted before.

A long course of reading and study of plant physiology, however, convinces me that such a parasitic action is possible, and the following passage from De Bary (*Comparative Morphology and Biology of the Fungi, Mycetozoa, and Bacteria*, p. 395) seems to me to be of profound importance to cancer research.

> "This case is an instance of *a parasite surrendering its individuality, so far as that can be recognised morphologically*, after its entrance into the host; it becomes changed into a part of its host and *the two can no longer be distinguished from one another by our present means of investigation. The parasite also communicates new properties to the host*, which is some two hundred times its size, and through them *the host develops into its own parasite.* This transmutation of the host by the parasitic spore which has coalesced with it, though peculiar, is yet *analogous with the fertilising effect of the spermatozoid on the oösphere* of organisms which in the sexual sense are highly differentiated from one another."

The italics are mine, but I think that no one familiar with the cytology of cancer who carefully weighs the italicised words can fail to be impressed by their importance. Here we have a parasite so behaving towards its host that its protoplasm is lost in that of its host, and that the cells of the host become its own parasite. Could anything more closely resemble the qualities of the cancer cell?

The organism referred to by De Bary is one known as *Rozella*, which is parasitic on a species of fungus known as saprolegniæ, which lives on dead animal matter.

Now this parasite *Rozella* is closely akin to another called *Plasmodiophora brassicæ*, which causes tumours in plants, and also to *Woronina*, the morphology and course of development of which are so strange that De Bary and others hesitate whether to class them among the myxomycetes as plants or among the protozoa as animals.

In the case of *Plasmodiophora brassicæ* we get the most remarkable example of plant malignancy. The amœboid protoplasm of the parasite lives in the protoplasm of the cells of the cruciferæ, to which it gains access through the root-hairs. It does not kill the cells, but stimulates their protoplasm to increased activity of growth and division. The externally visible result is the formation of distorted swellings on the root (popularly known as finger-and-toe, club-root or anbury), or ulcerating tumours on the bulbs.

The former are well illustrated in Figs. II. and III., the latter in the coloured frontispiece to this book.

The organism was discovered by Woronin in 1876 and described by him in 1878. Strange to say, even at that date he predicted that malignant growths in man might eventually prove to be due to a parasite of a similar nature. This hypothesis has been advocated from time to time, and Ford Robertson and Wade even claim to have (*Lancet*, 28th January 1905) demonstrated the presence in carcinomatous tumours of bodies corresponding in form, and in reaction to a special method, to fourteen phases in the strange life-cycle of *Plasmodiophora brassicæ*, and in growing from such tumours an organism accurately representing several successive phases of a parasite of this class. Both organisms were extremely difficult to stain; ordinary staining methods were found to be useless for the purpose, and special complicated staining processes had to be devised. Full details of these will be found in the paper itself. No one who compares in

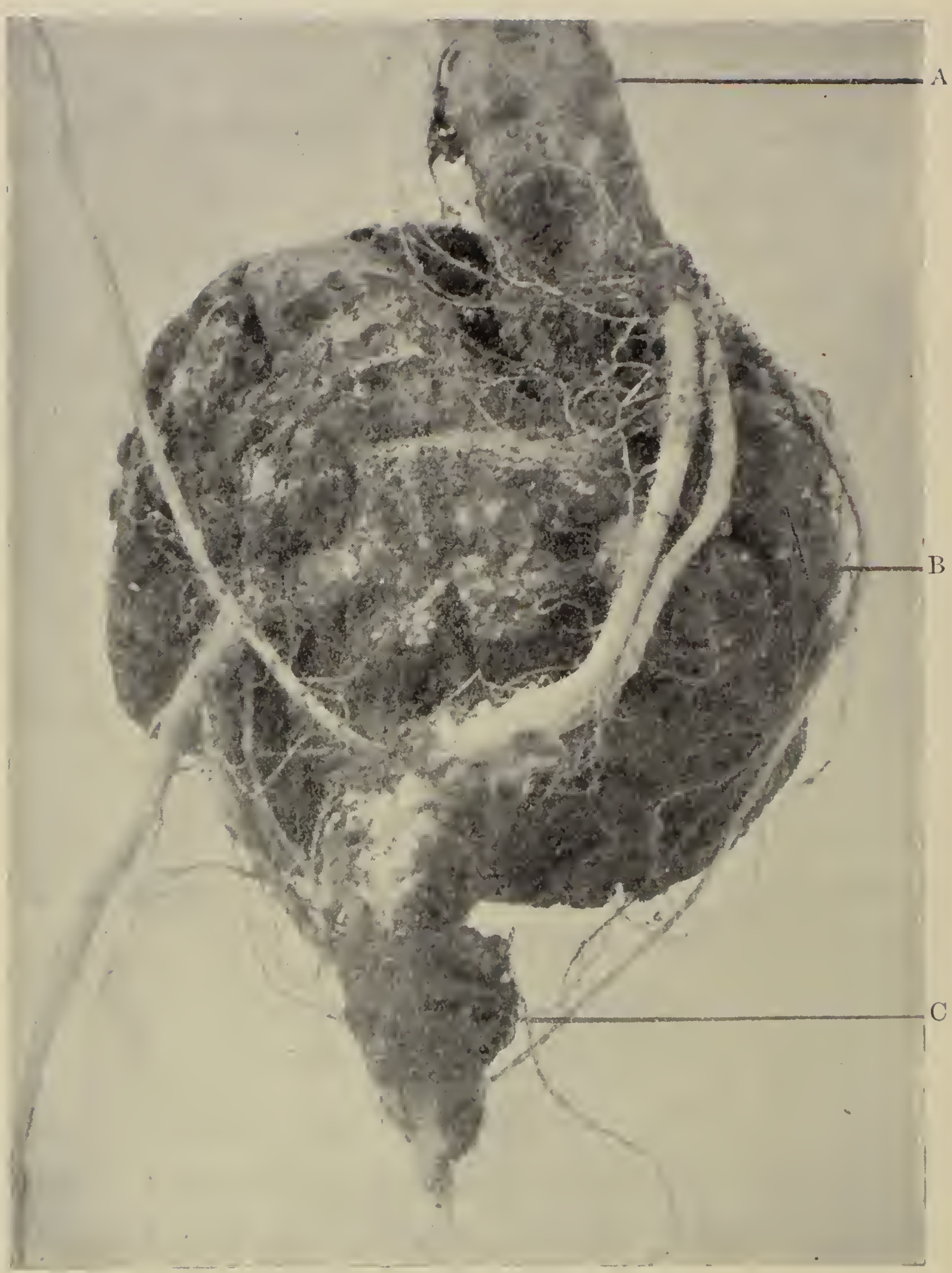

FIG. II.—Finger-and-Toe: large Tumour on the Root of a Cabbage Plant caused by *Plasmodiophora brassicæ*. A, Stem of Plant; B, Tumour, natural size; C, Smaller Growth on Rootlet.

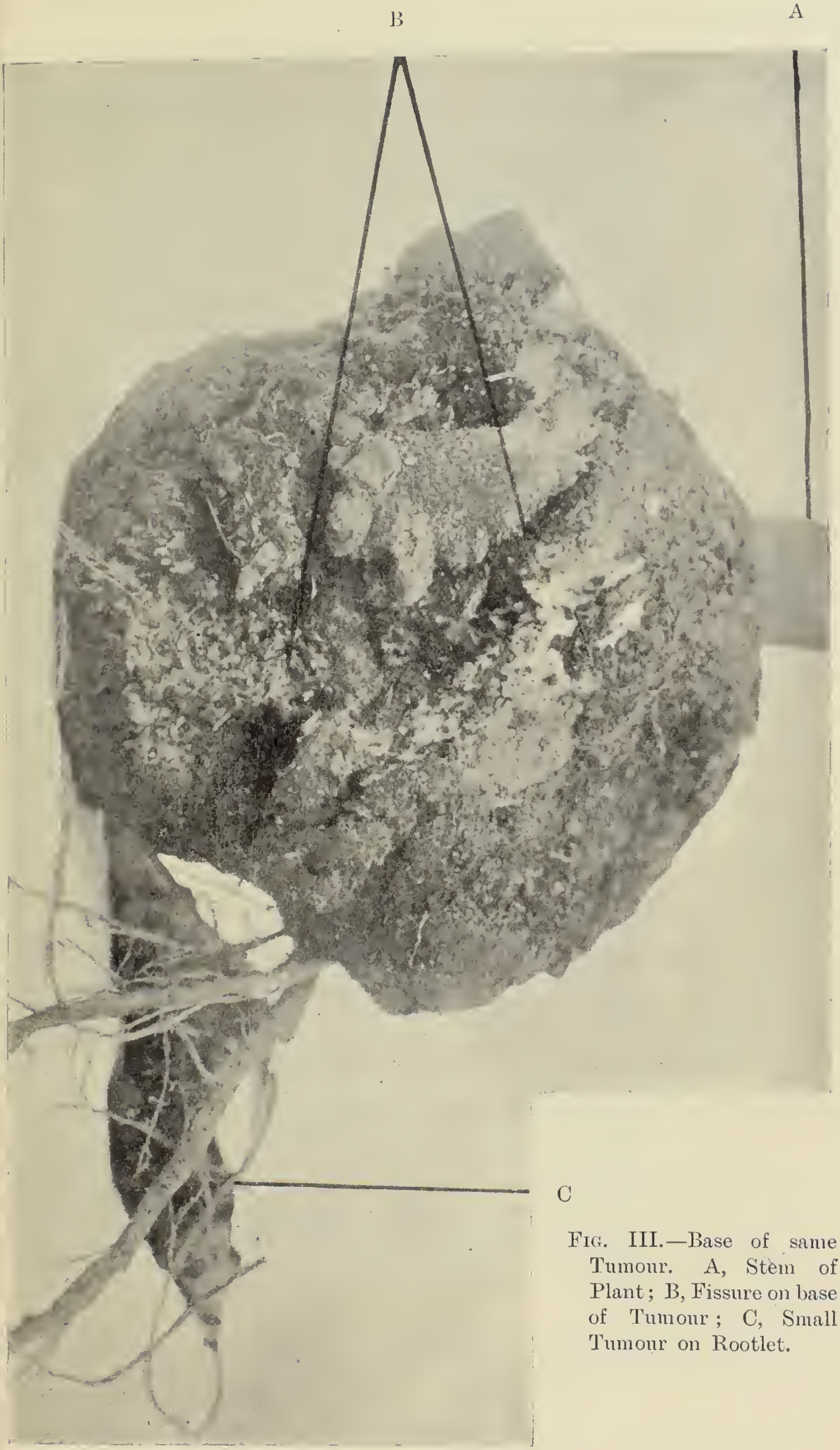

Fig. III.—Base of same Tumour. A, Stem of Plant; B, Fissure on base of Tumour; C, Small Tumour on Rootlet.

Fig. IV. the fourteen phases referred to can fail to be impressed by the marvellous similarity of A, *Plasmodiophora brassicæ,* and B, the organism called by the authors *Plasmodiophora carcinomatis,* and developed by them from carcinomatous tissue.

While many observers have detected organisms corresponding to stages in a similar life-cycle in malignant tumours, *e.g.* Russell's bodies and Plimmer's bodies, none have shown anything like this, which differs from that of others in the recognition of the granular and post-granular stages.

The life-cycle of *Plasmodiophora brassicæ* is one of the strangest things in Nature. It is one of the mycetozoa, of which the greater number belong to the subdivision myxomycetes or slime moulds (the myxogasteres of Fries).

These slime moulds are difficult to place. They at one time were classed with the protozoa, but this classification is now abandoned. If they are not protozoa, they are equally clearly not fungi, and are now classed in a group by themselves, regarding which biologists differ as to whether it should be considered among the plants or animals. (For further details, see Macbride's *North American Slime Moulds*—Introduction.)

If the hypha is the morphological test of a

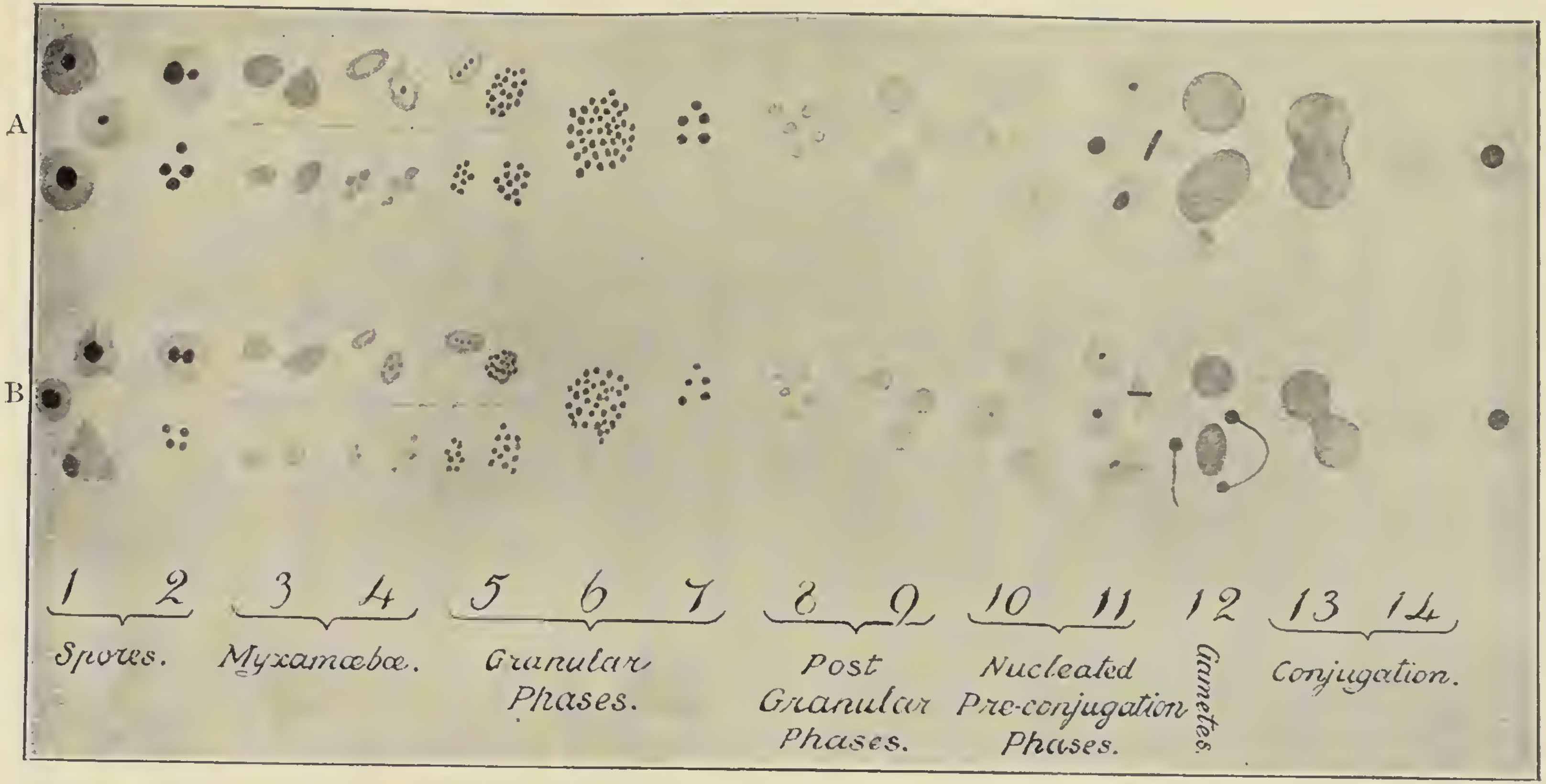

FIG. IV.—A, *Plasmodiophora brassicæ* ; B, *Plasmodiophora carcinomatis* (Ford Robertson and Wade).

fungus, then it is plain that the slime moulds are not fungi. No myxomycete has hyphæ or anything of the kind.

The fungi, however, are incapable of independent existence, being destitute of chlorophyll. In this respect the slime moulds are like the fungi; with the exception of *Plasmodiophora*, which is a parasite, they are nearly all saprophytes. All are destitute of chlorophyll. This physiological character is one which the fungi share with the whole animal world. That their amœboid spores and plasmodia ally them at once to the amœba is the position suggested by De Bary in 1858, and adopted since by many distinguished authorities, among whom may be mentioned Saville Kent and Dr. William Zopf (*Die Pilzthiere*). Rostafinski, who was a pupil of De Bary's, and whose monograph on the slime moulds was written under De Bary's supervision, adopts the title "Mycetozoa," suggested by his master as indicating a closer relationship with the animal world, but really has little to say in regard to the matter.

In the course of their life-history the myxomycetes present two very distinct phases—the vegetative phase and the reproductive. The vegetative phase differs from that of all plants, since the organism then consists of a simple mass of protoplasm destitute of cell-walls *and in all respects an amœba.* In this state the myxomycetes affect damp and moist situations. They are found in soil, on piles of rotten leaves, in straw, and especially in the wet tissues of decayed wood.

The vegetative phase unquestionably justifies the views of those systematists who consider them animals. It may last for months or years, when the reproductive phase at length arrives and spores are formed, which germinate and pass through a regular life-cycle, ultimately to reach the amœboid condition again.

Regarding human tumours, many so-called parasites have been described. Protozoa of all groups have been held responsible by various investigators. Yeasts and bacteria have been described by others, but in no case has the claim been held good. It is only natural that such organisms should be found in so favourable a medium for growth as the degenerated tissues of the disease.

In the same way attempts have been made to explain the cell inclusions in human cancer as organisms by one set of observers, while others have shown them to be forms of degenerating cells.

In spite of this there are the strongest indications that cancer is parasitic in origin.

That the parasite has not been found is no argument for its non-existence. Although yellow fever is undoubtedly due to a parasite developed in the body of the mosquito, in which it must exist for twelve days before it can transmit the disease, this organism has never been seen. It will pass through the finest filters and is apparently ultra-microscopic.

If cancer be due to a parasite similar to *Rozella* or *Plasmodiophora* in its amœboid stage, it may well be that its detection is a matter of complicated staining. Meantime, the analogy is very strong, judging from malignant vegetable tumours, that some such amœboid, intracellular and possibly ultra-microscopic parasite does exist, and that it belongs to the mycetozoa, some members of which in certain cases *cause the cells of the host to act as its own parasite.*

CHAPTER II

THE OCCUPATIONAL INCIDENCE

If, then, cancer be due to a parasite akin to the myxomycetes, it is obviously of importance to understand the physiology and metabolism of such organisms and to discover whether there are any conditions in the trades showing the highest cancer death-rate which would encourage their growth.

Unfortunately very little is known regarding their conditions of life. Some work has been done in America and in certain agricultural colleges, but, as has been said, the entire group has been neglected owing to many zoologists considering them plants and many botanists animals. They are described in no text-books on protozoology or protozoa. In medicine they have not been considered pathogenic, and very few pathologists even know of their existence. Their study is naturally not included in any medical curriculum.

Pfeffer in his *Plant Physiology* (vol. ii. p. 121) states that a concentration of the external medium without any change in its composition causes them to produce perennating bodies, which are specially resistant to drought; that certain of them show a positive chemotactic movement towards extract of tan; that the spores of certain are attracted by lactic, butyric and malic acids; that their plasmodia are killed by exposure to light of moderate intensity, even feeble illumination distinctly retarding the amœboid activity and also the streaming of the endoplasm.

As to their nutrition, all that De Bary can say is, that they "live on organic substances, of course with the necessary ash constituents, and what definite chemical substance does actually and usually serve or is fitted to serve as nutrient material to the myxomycetes is a question which has not yet been thoroughly examined."[1] This is practically all that I have been able to discover.

When so little is known regarding the entire group of organisms known as myxomycetes, it is small wonder that so much obscurity exists regarding the small subclass which is parasitic and not saprophytic like all the others.

Agriculturists, however, have suffered severely from the ravages of one of the group, viz. Plasmodiophora, and one outstanding fact is given in all agricultural text-books as the result of their practical experience regarding it, that whenever manures are used which have been DISSOLVED IN SULPHURIC ACID the disease known as finger-and-toe and caused by *Plasmodiophora brassicæ* is very likely to occur.

---

[1] *Comparative Morphology of the Fungi and Mycetozoa.*

The Board of Agriculture in one of its official leaflets which are distributed gratuitously among farmers all over the country also puts it on record that manures which have been DISSOLVED IN SULPHURIC ACID have a marked tendency to encourage the disease (*Encyclopædia of Agriculture*, vol. ii. p. 106).

Jamieson, who has carried out a long series of scientific experiments on the effect of artificial manures in relation to Plasmodiophora and finger-and-toe, has shown that the use of dissolved phosphates in which sulphuric acid has been used to dissolve the phosphate renders the plants distinctly more liable to fall a prey to the disease.

If therefore :—

(1) SCIENTIFIC AGRICULTURE HAS MADE IT CLEAR THAT SULPHURIC ACID MANURES HAVE A STIMULATING EFFECT ON PLASMODIOPHORA,

(2) THERE IS THE STRONGEST PRESUMPTION, AS I HAVE TRIED TO SHOW IN THE FIRST CHAPTER, THAT CANCER IS DUE TO A SIMILAR CLASS OF ORGANISM,

is it not probable that the trades which show constantly the highest cancer death-rate may work under conditions which stimulate the growth of a parasite in a similar fashion?

One would naturally first of all think of sulphuric acid itself, but so far as I can discover this alone does not cause cancer, for the following reason:—As is shown by the Registrar-General, papermakers are almost immune from malignant disease. Now in only one or two mills in this country and in France a private process is carried out for making vegetable parchment by the use of large quantities of sulphuric acid. I have letters from every such mill in Great Britain to the effect that cancer was unknown among the men constantly working with the acid, while a friend who inquired personally at each of the French mills got the same result. This instance seems conclusive, as here we have a group of men belonging to a trade which is otherwise practically immune brought into constant contact with H_2SO_4 and with a negative result.

Strange to say, it has lately been shown that sulphuric acid alone does not induce finger-and-toe in the cruciferæ which have been grown in soil impregnated with it without the disease resulting.

If, then, sulphuric acid alone does not induce the disease, the active agent must obviously be sulphuric acid in combination with some other substance or some sulphur compound.

What agricultural experience has shown to most frequently cause the disease is the manure known as dissolved bones, *i.e.* a quantity of bones placed in a receptacle over which sulphuric acid is poured. The change which the acid effects on the bones is shown by the following analyses :—

Raw Bones

	Bone Meal.	Bone-Char (dry) after treating Bones in Closed Retorts.
Moisture . . .	10·43	...
Organic matter[1] . .	32·30	10·51 (carbon)
Phosphates of lime and other bases . . .	48·40	80·21
Carbonate of lime, magnesia, etc. . . .	7·20	8·47
Insoluble silicious matter, ferric oxide, and alkalies .	1·67	0·81
	100·00	100·00

[1] Containing 3·71 of nitrogen = 4·51 of ammonia.

BONES DISSOLVED IN H_2SO_4

Moisture	10·10
Organic matter and water of combination[1]	29·34
Monocalcic phosphate of lime	11·23
(Equal to tricalcic phosphate rendered soluble, 17·58)	
Phosphate soluble in ammonium citrate	14·02
Insoluble phosphate of lime	1·88
Calcium sulphate, etc.	30·23
Sand and impurities	3·20
	100·00

What element in the latter table induces finger-and-toe and fosters Plasmodiophora it is difficult to suggest, but there is no doubt as to the formation of a large proportion of calcium sulphate, and that blocks of gypsum, which is calcium sulphate combined with $_2(H_2O)$, are the regular method for the cultivation of the spores of saccharomycetes in laboratory practice, as a richer spore formation is got on gypsum than on other substrata (Klöcker, *Fermentation Organisms*, p. 64). This result is due not only to the effect of the calcium sulphate on the yeast, but also to the fact that it prevents the growth of bacteria (Klöcker, p. 65).

Hansen, who is the greatest authority on yeasts, brought out a remarkable fact in connection with spore formation in relation to calcium sulphate, namely, that the spore itself can occur as a spore mother-cell. This happens when the spore, after being a short time in a culture liquid containing sugar, has swelled up and is then transferred to an aqueous solution of calcium sulphate. *No buds are then produced, and instead spores are formed in the interior of the swollen spore* (Klöcker, p. 205). This fact is of great importance in relation to cancer cytology.

---

[1] Containing nitrogen, 2·62=3·18 ammonia.

It should also be borne in mind that the lower fungoid organisms flourish best when sulphates are present as part of their inorganic nourishment. The sulphate can be effectively replaced by thiosulphate or sulphur, but not by thiocarbamide, potassium sulphocyanide, or sulphonal (Matthew's *Alcoholic Fermentation*, p. 277), and also that they can *directly use* sulphurous acid and hydrosulphurous acid (H_2SO_3, H_2SO_2), if present in sufficient dilution to be non-poisonous (Pfeffer, *Plant Physiology*, vol. i. p. 429).

In view of these considerations I have examined carefully the working conditions in the trades which have been shown by the Registrar-General to have a very high cancer death-rate, and venture to think that there are very striking indications of such influences as I have indicated.

The last complete returns of the Registrar-

General were issued in 1908 and covered the period from 1900 to 1902. The comparative mortality figure from cancer in the various trades is given as follows. It is difficult to understand the system of selection of the trades which has been made, but they are given exactly as published.

OCCUPATION.	COMPARATIVE MORTALITY FIGURE FROM CANCER.
CHIMNEY-SWEEP	136
INN-, HOTEL-SERVANT (LONDON)	133
GENERAL LABOURER (INDUSTRIAL DISTRICTS)	116
BREWER	112
FURRIER, SKINNER	111
GENERAL LABOURER	111
SEAMAN, ETC., MERCHANT SERVICE	103
GENERAL LABOURER (LONDON)	102
TINPLATE MANUFACTURER; TINPLATE GOODS MAKER	95
DOMESTIC COACHMAN, GROOM	94
INNKEEPER, SERVANT, ETC., IN LONDON	94
INN-, HOTEL-SERVANT	88
CHEMICAL MANUFACTURE	85
LEAD MANUFACTURER; LEADEN GOODS MAKER	82
INDIARUBBER, GUTTA-PERCHA WORKER; WATERPROOF GOODS MAKER	82
BOTTLE-MAKER	82
WOOD TURNER, COOPER, ETC.	80
TEXTILE DYER, BLEACHER, PRINTER, FINISHER, ETC.	79
TRAMWAY SERVICE	79
COSTERMONGER, HAWKER, ETC.	79
MESSENGER, PORTER, ETC. (NOT RAILWAY OR GOVERNMENT)	79
LACE MANUFACTURE	79

OCCUPATION.	COMPARATIVE MORTALITY FIGURE FROM CANCER.
GENERAL SHOPKEEPER	78
CABINETMAKER, ETC.	75
BARGEMAN, LIGHTERMAN, WATERMAN	75
COAL-MINER	51
SILK, SATIN, CRAPE, ETC., MANUFACTURE	51
SADDLER, HARNESS-MAKER	51
FARMER, GRAZIER, FARMER'S SON, ETC.	51
BRUSH-, BROOM-MAKER; HAIR-BRISTLE WORKER	51
SCHOOLMASTER, TEACHER	49
INN-, HOTEL-SERVANT (INDUSTRIAL DISTRICTS)	49
CLERGYMAN, PRIEST, MINISTER	48
AGRICULTURIST	48
PLATELAYER, RAILWAY LABOURER; NAVVY, ETC., ROAD LABOURER	48
GARDENER, NURSERYMAN, SEEDSMAN	48
RAILWAY ENGINE-DRIVER, STOKER	48
FARMER, GRAZIER, ETC., IN AGRICULTURAL DISTRICTS	46
COAL-MINER (MONMOUTHSHIRE AND SOUTH WALES)	46
FARM LABOURER, FARM SERVANT	45
COAL-MINER (LANCASHIRE)	44
AGRICULTURIST IN AGRICULTURAL DISTRICTS	44
COAL-, COKE-MERCHANT, DEALER	44
LABOURER, ETC., IN AGRICULTURAL DISTRICTS	42
COAL-MERCHANT; COKE-BURNER, ETC.	42
LOCK-, KEY-, GASFITTINGS-MAKER; GASFITTER	41
WHEELWRIGHT	40
COPPER MINER	39
PAPER MANUFACTURER	39
COPPER MANUFACTURER, WORKER; COPPERSMITH	39
TANNER	33

It is interesting to compare this table with a previous one which was issued about twenty years ago and which is printed below.

OCCUPATION.	COMPARATIVE MORTALITY FIGURE FROM CANCER.
CHIMNEY-SWEEPS	156
INNKEEPERS IN LONDON	70
BREWERS	70
INN AND HOTEL SERVANTS	65
COMMERCIAL TRAVELLERS	63
MALTSTERS	61
MERCHANT SEAMEN	60
LAWYERS	60
GAS WORKERS	59
TOOL AND SCISSORS MAKERS	58
COACHMEN AND GROOMS	58
BUTCHERS	57
COAL-HEAVERS	56
INNKEEPERS	53
PLUMBERS	53
TOBACCONISTS	51
DOCK AND WHARF LABOURERS	51
SHOEMAKERS	50
DRAPERS	49
GENERAL LABOURERS	48
PORTERS	48
FISHERMEN	46
BLACKSMITHS	45
MEDICAL PRACTITIONERS	43
FISHMONGERS	42
FARMERS	36
COAL-MINERS	36
POTTERS	35
CLERGY	35
GROCERS	34
ALL UNOCCUPIED MALES	96
ALL OCCUPIED MALES	44

Chimney-Sweeps.—Two striking facts are shown by a comparison of these tables: (1) That the chimney-sweep has by far the highest cancer mortality figure of all trades; and (2) that in the first and later table the percentage of the chimney-sweep has decreased while that of all other trades has increased. In the last published report of the Registrar-General this decreasing cancer mortality of chimney-sweeps is specially referred to, and it is also stated in Table 7 of the report that ever since 1860 the mortality in this occupation has declined continuously to such an extent that the present figure is only two-thirds of what it was at that date.

Now, whatever bearing it may have upon this point, it is certainly an interesting fact that the year 1840 marked the passing of the Chimney-Sweepers and Chimney Regulation Act which forbade any person to allow a child or young person under the age of twenty-one to ascend or descend a chimney or enter a flue for the purpose of sweeping or coring the same, as had previously been the regular custom. This Act was made more stringent in 1864. It forbade a chimney-sweeper even to bring a young person into a house with him. Previous to this period, house chimneys had been built wide and square in order that children might clean them in this way. Afterwards, when they had to be swept with brushes, it was found that the round chimney was more easily cleaned, and the present narrow clay tube chimneys came gradually into invariable use. The old chimney with its rough stone-and-lime surface must have been considerably dirtier than the modern one.

Whether this point has any bearing or not upon the decreased death-rate among sweeps, there is no doubt that in the text-books soot is said to cause epithelioma, by irritation, presumably mechanical. This, however, is not a satisfactory explanation, since the disease is rare among working coal-miners, whose skins are saturated with carbon in the shape of coal-dust, which should be equally irritating.

Although the mechanical irritant theory is not satisfactory, there is no doubt whatever that soot, or some product of combustion, is an active agent.

Ordinary coal soot has a deleterious effect upon the leaves of plants, and this was formerly ascribed to mechanical irritation or to the blocking of the stomata through which the plants breathe. Stockhardt, however, proved this to be wrong by an experiment, eighty-six times repeated, in which he filled a glasshouse with an atmosphere of soot from burnt benzine so thick that the contours of the plants could not be seen, and that the leaves were almost black. No disturbance of growth could be detected, and the leaves were afterwards as fresh as those outside. The pure carbon soot from the benzine had no effect, while coal soot had.

In a similar fashion the carbon in coal does not cause cancer in the miner, while the soot affects the sweep.

The fact that coal soot has a close relation to the sweep's high mortality is also, I think, indicated by the part of the body chiefly affected, as shown by a table in the Registrar's latest report. This table shows that in 30 per cent. of the deaths the scrotum and its adjacent parts are those affected. Now the face of a working sweep will always be found to be covered with light powdery soot, while his hands and nails are absolutely black and coated. The extremities are not liable to malignant disease, but these soot-engrained hands must for obvious reasons several times in a working day come in contact with the susceptible parts which are associated with "sweep's cancer."

At one time I thought it possible that scrotal cancer might be caused by proximity to the fumes from chimney heads when working, as these would be on the same level approximately as the sweep's scrotum. This idea, however, is negatived by the facts that scrotal epithelioma occurs in guano workers, and that in the report of the Royal Commission appointed to inquire into the condition of boys who used to clean chimneys by climbing up them, there is medical evidence to the effect that boys of tender years were operated on for scrotal cancer.

An additional proof that the disease is fostered by a product of combustion is the Kangri basket with which the natives of Kashmir warm themselves in winter. This is a basket containing a clay pot in which burning coal or charcoal is placed and is worn next the skin under the clothes. Enormous cancers develop upon the abdomens of many of the wearers. A surgeon who has both seen and operated on these unique malignant tumours informed me that it was only when the basket portion was destroyed and the sooty clay came in contact with the skin that the disease arose.

If soot, then, be an active agent in producing malignant disease, as is shown by the appalling mortality among chimney-sweeps and by other indications, while coal-dust has no effect upon the coal-miner, it is obviously of importance to consider what soot contains which coal does not.

Coal soot is chiefly composed of finely divided carbon, but it also contains a considerable proportion of SULPHATE OF AMMONIA. Coal contains sulphur and nitrogen, and in the process of combustion ammonia and sulphurous acid are evolved, which combine to form the above-named salt. It is the existence of sulphate of ammonia in large quantities in soot that has led to its use as a fertiliser by farmers and gardeners.

Here, however, a difficulty presents itself. If, by the above process of reasoning and of elimination, one is led to the conclusion that sulphate of ammonia or the sulphurous acid which goes to compose it is an etiological factor, how are we to reconcile this result with the fact that paraffin has induced among **paraffin workers** cancerous growths in several well-authenticated cases? This for a long time puzzled me. I was at first led astray by the fact that the chief source of commercial sulphate of ammonia is mineral oil works, but this cannot affect the question, as ammonia water is the only real by-product, and the sulphuric acid necessary to combine with this and form the ammonium sulphate is bought in and added in a separate department of the works, having no connection with refined paraffin.

The puzzle was to find whether there was anything in common between commercial paraffin and soot. When we examine the practical methods of paraffin refining we find that in order to remove the oily bases it has been found in practice that an acid treatment of the finished oil is necessary. It is not possible to remove the whole of these bases by one or even two acid treatments, but the oil must be *shaken up with acids a number of times.* All kinds of acids have been tried, but the results of numerous experiments have proved *sulphuric acid* to be the only one suitable for this work. It is specially pointed out in Redwood's *Mineral Oils* as of the utmost importance that all such sulphuric acid treated oils must be allowed to settle until as thoroughly freed from this acid tar as possible.

In removing the impurities the sulphuric acid must form various sulpho-acids, which must frequently be present in the paraffin after the operation. It would be a difficult matter to say what were the sulpho-acids, as there might be, of course, fifty different varieties, entirely depending on what the impurities were. There would certainly be no sulpho-acids of the paraffin itself, as this remains unacted on, and it is only impurities that are acted on.

One impurity which is bound to exist, however, is ammonia — since the method of separation of ammonia water from the crude oil is a very rough and ready one — and we are driven to the result that even *in refined paraffin, as in soot, sulphate of ammonia must often exist.*

When the mortality figure tables of the Registrar-General are scrutinised in the light of these facts there are several curious corroborations in the conditions affecting the other trades most liable to malignant disease which may be mentioned here.

I propose first to take the highest of these in order and state facts which I have elicited after a good deal of trouble.

Brewer.—It has been abundantly proved that the consumption of alcohol has no connection with cancer. Indeed, one has only to bear in mind the fact that women, who as a class are more temperate than men, are more liable to the disease, and that many abstainers have suffered from it, to be satisfied on this point. The brewer's high mortality rate is therefore extremely interesting. His work is conducted among wort boilers and other vessels heated by fire and so constructed that the maximum of flame may get round them. The lower flues are generally horizontal, and many interstices permit and encourage the accumulation of soot.

The mortality figure of brewers has also greatly increased in recent years. I have examined breweries and brewing methods most carefully in the endeavour to discover the cause of this.

One curious fact I have elicited is that the caramel which is used to colour all beers was formerly only made from burnt sugar, but in order to make the substance tasteless it is now prepared by charring the sugar with sulphuric acid.

The brewer is also constantly handling "sulphured" hops. The object of sulphuring hops—that is, using sulphur with the fuel when drying hops—is to bleach them and make them brighter. The sulphur itself in the hops, and therefore in the beer, exists as sulphurous acid (Moritz and Morris, *Science of Brewing*, p. 199).

Again, in nearly all beers antiseptics are now used, the one in almost universal use being bisulphite of lime, which is prepared by saturating a solution of sulphite of lime with sulphurous acid. It is sometimes used in the mash, sometimes in the copper, but much more frequently in the finished beer. Other sulphites used are sulphite of sodium, sulphite of potassium, sulphite of magnesium, etc. The only substance other than a sulphite which is at all largely employed is salicylic acid (Moritz and Morris).

Finally, in brewing, large quantities of what is known as "brewer's glucose" are used, and this is prepared by hydrolysing potato starch by boiling with sulphuric acid.

Furrier.—It is a very strange and instructive fact that the *furrier* should be almost at the *top* of the list while the *tanner* is at the *bottom.* The cause must be due to some difference in the methods of preparing skins for furs and for leather. In the former case the hair must be preserved, in the latter entirely removed. The tanner steeps his hides in lime, which, as will be shown later, is apparently prophylactic, while the furrier adopts a different process. The skins of mammals, we are told (*Ency. Brit.*, xxiii. p. 90), are best preserved by a mixture of 4 parts burnt alum to 1 part of saltpetre. Alum, it must be remembered, is composed of sulphuric acid, alumina, an alkali, and water. Nearly all furs have also to be dyed, and the mordant used is chiefly sulphuric acid.

Seamen have shown a great increase in their cancer mortality, due apparently to the increase of steamers and the decrease of sailing ships. The fact that they have a higher mortality figure than fishermen seems to me to be due to this and to their stuffy and smoky quarters. Fishermen do not so often sleep on board; indeed the greater number never do.

Tinplate Manufacturer.—What element in the manufacture of tinplate can cause this very high mortality figure? If my theory is correct, this would explain it: "Before 'tinning,' the plates are called black plates. When the iron has been cut to the required size the plates are 'pickled,' *i.e.* they are immersed in hot sulphuric acid."—*Chambers's Ency.*, x. p. 217.

Domestic Coachman.—The cancer mortality figure among coachmen and grooms is strangely high. It is difficult to understand why the Registrar should have given a special figure for the domestic coachman and not one for ordinary stablemen and drivers generally, but we must take it as we find it. It can have no connection with the stable itself or with the horse as an animal, since the agriculturist, who also works among horses, has a very low cancer mortality.

I believe that the domestic coachman's high mortality figure is due to his home. This in towns is always in a mews behind higher adjoining buildings, and the question of the relation of such buildings to cancer is dealt with in the next chapter on the local incidence of the disease.

Chemical Manufacturers.—The intimate connection of these trades with sulphur compounds and ammonia is at once obvious. It is unfortunate, however, that the figures are not given for different classes of chemical workers, since it has been strongly claimed by competent observers that cancer is unknown among workers with certain primary acids and chlorine products, and common among workers with odourless and non-volatile chemicals. An interesting correspondence on this subject occurred in the *Standard* in April 1905.

Lead-workers.—Here we have a close connection with sulphurous acid. It is pointed out in the last Report of the Registrar-General that the cancer mortality of lead-workers had decreased since 1890. Now until recent years only a small quantity of lead was obtained from any other ore than galena, which is a sulphide of lead. When galena is smelted, much of the sulphur goes to form sulphurous acid, which escapes as a gas. There remain in the hearth of the furnace oxide, sulphate, and sulphide of lead, which react upon each other, forming sulphurous acid and metallic lead.

Indiarubber-workers.—The connection here is obvious since alum and sulphuric acid are constantly used to effect the coagulation of the juice, and traces of these remaining in the rubber constantly work mischief in it.

As to the intimate connection between indiarubber-workers and sulphur compounds, all that is necessary is to quote the following paragraphs from the last edition of the *Encyclopædia Britannica*, vol. xxiii. p. 802:—

"Most articles made of rubber would be of very limited utility were they not hardened by the action of sulphur or some compound of that element. It must, however, be distinctly understood that it is not the mere admixture but the actual combination of sulphur with indiarubber that causes this. If an article made of cut sheet rubber be immersed for a few minutes in a bath of melted sulphur maintained at a temperature of 120° C., the rubber absorbs about one-tenth of its weight of that element, and although somewhat yellowish in colour from the presence of free sulphur, it is still unaltered as regards general properties. If, however, it be now subjected for an hour or so to a temperature of 140° C. a combination occurs.

"When a manufactured article has been saturated with sulphur in the melted sulphur bath the heat necessary may be obtained either by high pressure steam, by heated glycerine or by immersion in a sulphur bath heated to about 140°. In this last case absorption of the sulphur and its intimate combination with the rubber occurs simultaneously. Cut sheets may be saturated by being laid in powdered sulphur maintained for some hours at 110°.

"Another method consists in exposing the sheets to the action of chloride of sulphur."

Occupations in London.—Nearly all the occupations "in London" for which a figure is given are higher than those elsewhere. This is probably due to the enormous amount of sulphur and of acid in the air of London. This excess has been often pointed out.

In addition to the trades mentioned in the Registrar-General's statistics there are several occupations which are notoriously liable to cancerous infection, *e.g.* :—

X-ray Workers.—In this imperfect survey of the trade and occupational incidence of the disease I would venture to make a suggestion regarding what is called X-ray cancer, which so commonly follows a dermatitis on the hands of X-ray workers. It is certainly one of the most puzzling aspects of the whole cancer problem that X-rays should cure rodent ulcer and yet induce epithelioma on the fingers of the operators of these rays.

If, as stated before, the plasmodia of myxomycetes are killed by exposure to light of moderate intensity, it is quite intelligible that X-rays should cure cancer, but quite unintelligible that they should cause it.

The X-rays admittedly cause a dermatitis and thereby diminish the resistance of the epithelium. It should not be forgotten, however, that most X-ray operators have to prepare many skiagraphs and to develop negatives. This, in my opinion, is the cause. Fixing plates by means of hypo-sulphite with fingers, the skin resistance of which is already weakened, is much more likely to cause the epithelioma than the rays themselves. These would only indirectly be concerned.

Guano-workers.—In the new edition of Bryant and Buck's *Surgery* it is stated that scrotal cancer nowadays is found among workers in guano as well as among chimney-sweeps and coal-tar workers. This seems inexplicable until one realises that the richest deposits of guanos have been largely worked out, and that the stores now largely drawn upon are in many cases compact and rocky in texture, and require now to be disintegrated and treated with sulphuric acid (*Encyclopædia of Agriculture*, vol. ii. p. 287).

Coal Tar Workers.—It has long been known that workers in coal tar and creosote were especially liable to epithelioma, and the Home Office has recently added a new interest to the subject by the issue of proposed regulations regarding workers with gasworks tar pitch, in which the interesting exception is made that these rules are not to apply to workers in *blast furnace* tar pitch, since Dr. Whitelegge, the chief inspector of factories, could not find similar cancerous conditions among the workers in blast furnace pitch (*British Medical Journal*, 15th April 1911, p. 885). This observation coming from so high an authority is of great interest and importance from the point of view of cancer research.

If gasworks tar pitch causes cancer and blast furnace tar pitch does not, it is clearly of importance to compare their composition.

Blast furnace tar is altogether different from ordinary gas retort tar and cannot be employed for the same purposes.

Most blast furnaces are, of course, fed with coke from which no tar can be got. In the West of Scotland, however, a coal is got which is suitable for furnace purposes. The tar from this is not obtained from retorts but condensed from the enormous volume of gas issuing out of the blast furnace throat. This gas is carried to a separate plant and in nearly all cases is treated by the Gartsherrie process, which consists in simply cooling it down and washing it with water. The result is a pure tar in which even anthracene cannot be detected, and in which there is a much larger proportion of phenols than is obtained in gas coal tars.

Coal tar pitch made in gasworks, on the other hand, is an extremely complex mixture of chemical compounds, some of which have not yet been even isolated. It contains nitrogenous compounds chiefly of a basic nature and *sulphur compounds* derived from the pyrites, etc., never absent in coal.

Free sulphur has been found by Kehlstadt in the distillates of coal tar. Lunge considers it is formed from SO_2 and H_2S under the action of water.

There must also always be present in coal tar :—

Hydrogen Sulphide H_2S.
Ammonium Sulphide $(NH_4)_2S$.
Ammonium Sulphocyanide $(NH_4)NCS$.
Sulphur Dioxide SO_2.

LUNGE, p. 225.

Carbon Bisulphide CS_2 has also been found in as great quantity as 6 per cent. by Watson Smith in the first runnings of benzol from London gas tar, while Greville prepared it on a large scale from the purifiers.

Carbon Oxysulphide COS is, according to Lunge, bound to exist.

C_4H_4S, C_5H_6S and many sulphuretted bodies have also been found.

It is obvious, therefore, that many sulphur compounds exist in coal tar pitch which are not to be found in blast furnace tar pitch, and it must further be borne in mind that, according to the Alkali Inspector's reports, 95 per cent. of the gasworks pitch made in England is sold in the medium hard stage after distilling up to hard pitch and *softening it with creosote oil.* It is also revivified by means of creosote oil. Now creosote oil is in itself a cause of cancer, and Lunge (*Coal Tar*, p. 523) indicates that its unpleasant and nauseous smell is due to sulphur compounds not yet isolated.

We are thus driven to the conclusion that the difference between blast furnace tar pitch which does *not* induce epithelioma and gasworks tar pitch which *does* is chiefly the sulphur compounds contained in the latter, and also in the creosote oil which is used to soften it.

In dealing with the occupational incidence, however, we must remember that there is another side to the question, and that although some trades have a very high cancer death-rate, other trades have a very low one.

If it is probable that the conditions affecting the trades showing the highest cancer mortality figures might furnish a clue to the etiology, it seems equally probable that some light might be thrown upon the prevention, and, conceivably, even the cure, of malignant disease by an inquiry into the conditions affecting those occupations in which it occurs with least frequency.

From the Registrar-General's latest returns it will be seen that these trades are *tanners*, which show the lowest comparative mortality figure, 33 ; *papermakers*, comparative mortality figure 39 ; and both *copper-workers* and *copper miners*, which also show a mortality figure of 39.

Copper-workers and copper miners work with copper under totally different conditions, a fact which is rather striking, and goes to prove that there is something in the metal itself which is inimical to cancer. The salts of copper, it should be noted, are very powerful fungicides, and sulphate of copper is a constant ingredient in all mixtures used for fungoid diseases in plants, such as the well-known Bordeaux mixture (Bouillie Bordelaise) and

Burgundy mixture, used originally for spraying vines attacked by phylloxera.

Tanners and Papermakers.—The other two trades, viz. tanners and papermakers, seem at first sight to have little in common. It has been said already, however, that the tanner, unlike the furrier, WORKS LARGELY WITH LIME. In order to remove the hair the hides have to be steeped in lime pits, and enormous quantities of lime are used for this purpose. The papermaker, again, prepares his fibre, from which the paper is made, by bleaching it with strong chloride of lime. A fair-sized mill will use from twenty to thirty tons of chloride of lime every week, and the strong smell of chloride of lime is continually felt all over every paper mill and its surroundings.

Now, to revert for a moment to the question of *Plasmodiophora brassicæ*, it is a commonplace among farmers, and is mentioned in every agricultural treatise, that the only known method of eradicating this organism from land is by the use of lime. Further, plants suffering from the disease are never found on calcareous soils, nor on soils which are heavily charged with lime (*Encyclopædia of Agriculture*, vol. ii. p. 104).

Dr. Marshall Ward, than whom there is no higher authority, in his work on *Disease in Plants*, says:

"Finger-and-toe, due to Plasmodiophora, has been successfully dealt with by the application of lime, but we do not know whether the effect is owing to indirect action on the soil, to direct action on the plasmodia, or to the increased production of root hairs caused by the liming."

Again, the Board of Agriculture official leaflet, No. 77, says: "Finger-and-toe is practically unknown on soils naturally containing a high percentage of lime. The artificial application of burned lime has long been practised as a preventive, and this substance is still the most effective agent that is known. Other forms of lime are more or less effective, though none is so powerful as common burned limestone. Chalk has also a preventive influence, though its effects are weaker than those of burned lime, and from two to three times as much should be applied."

If the theory which I have tried to enunciate in the preceding pages be based on a fallacy, this matter of lime is of no importance. If, on the other hand, there be anything in the opinions of those who believe that cancer is due to an organism akin to the myxomycetes, the question of the relation of calcium to the prevention and even the cure of cancer may be of supreme importance. It is dealt with, however, more fully in the concluding chapter.

CHAPTER III

THE LOCAL INCIDENCE

It has been argued on the theory of probabilities that the so-called cancer houses do not exist. However this may be, it is unquestionable that there are most striking topographical variations in the incidence of the disease. In proof of this it is unnecessary to refer to the various papers and reports which have been prepared on various parts of the country in view of the fact that we again have the figures of the Registrar-General to deal with. How amazing these figures are is shown by the following table dealing with the registration districts of London alone. In this table I have had worked out to two decimal points from the last published figures, IN COLUMN ONE THE NUMBER OF CANCER DEATHS IN PROPORTION TO DEATHS FROM ALL OTHER DISEASES, AND IN COLUMN TWO THE NUMBER OF CANCER DEATHS IN EACH DISTRICT IN EVERY 100 DEATHS FROM ALL CAUSES. We have thus the amazing fact that cancer accounts for 1 death in every 5·88 deaths from all causes in St. Marylebone, while it only accounts for 1 death in 54·10 from all causes in Stepney. In other words, cancer is 10 times as common in St. Marylebone as it is in Stepney.

Proportion of Cancer Deaths to Deaths from all Other Causes in London.

Registration Districts.	One in	Per cent.	Registration Districts.	One in	Per cent.
1*a*. Paddington	10·02	9·98	16. Bethnal Green	20·25	4·93
1*b*. Kensington	10·11	9·88	17. Whitechapel	13·36	7·48
2. Hammersmith	14·67	6·81			
Fulham	21·31	4·69	18. St. George's in the East	35·26	2·83
3. Chelsea	8·17	12·24	19. Stepney	54·10	1·84
4. St. George's, Hanover Square	8·85	11·30	20. Mile End, Old Town	20·98	4·76
5. Westminster	10·57	9·46	21. Poplar	17·47	5·72
6. St. Marylebone	5·88	17·00	22. Southwark	20·80	4·80
7. Hampstead	9·27	10·78			
8. St. Pancras	10·76	9·30	23. St. Olave (Bermondsey)	22·29	4·48
9. Islington	12·60	7·93	24. Lambeth	11·90	8·40
10. Hackney	12·22	8·10	25. Wandsworth	13·70	7·30
11. St. Giles	17·75	5·63	26. Camberwell	13·36	7·41
12. Strand	7·92	12·62	27. Greenwich	16·59	6 02
13. Holborn	23·54	4·24	28. Lewisham	13·58	7·36
14. London, City	9·63	10·38	29. Woolwich	16·90	5·91
15. Shoreditch	22·45	4·45			

I have had the whole of England worked out on the same system and with similar surprising percentages. In the following remarks, however, I prefer to deal with slightly older figures relating to Scotland, partly because I am a Scotsman and know my native country more intimately in all its parts, and partly in view of the work of Dr. Aitchison Robertson to which I refer below.

The figures, showing the percentages for the whole of Scotland for the three years 1895, 1896 and 1897, will be found in the *Edinburgh Medical Journal* for January 1903, page 23, in a most valuable article by Dr. W. G. Aitchison Robertson, who took the trouble to correct them by allocating to their own places of residence patients who had been removed to hospitals and infirmaries for treatment and had died there.

As Dr. Robertson points out, at present our only means of treating the disease is by surgical interference, and consequently a large proportion of cancer cases are sent to hospitals or infirmaries in the large towns for operation. Many of these patients die away from their usual places of residence and in this way the mortality from cancer is unduly raised in many towns, while the reverse holds as regards country districts.

In order to counteract this registration error Dr. Robertson personally visited the larger institutions in Edinburgh and in other large towns in Scotland, extracted from their registers all the patients who had died from cancer in these institutions during the years in question, and apportioned them to their proper towns and counties. This examination must have involved an enormous amount of labour, but the result is a set of statistics of great value, and the tables are appended—

Table showing the Percentage of Cancer Deaths, as Calculated from the Returns of the Registrar-General for Scotland (first column), and as Corrected. **The average for the whole of Scotland for the three years 1895-6-7 was 4·023 per cent.**

	Registrar-General.	Corrected.		Registrar-General.	Corrected.
Principal Towns—			*Large Town Districts*—contd.		
Glasgow	3·12	2·98			
Edinburgh	5·15	4·03	Rutherglen	1·93	2·14
Dundee	4·17	4·09	Galashiels	5·19	...
Aberdeen	4·65	4·53	Hawick	4·86	5·27
Govan and Partick	2·65	2·8	Dumfries	4·56	4·61
Leith	3·87	4·11			
Paisley	3·16	3·2			
Greenock	3·04	3·12			
Coatbridge	2·69	...	*Small Town Districts—*		
Perth	4·06	4·29			
Kilmarnock	3·80	...			
			Shetland	3·33	...
			Orkney	3·42	...
Large Town Districts—			Caithness	4·49	...
			Ross and Cromarty	4·80	...
			Nairn	4·11	...
Inverness	5·02	5·25	Elgin	3·92	...
Peterhead	2·79	...	Banff	4·88	...
Arbroath	4·76	...	Aberdeen	4·75	...
Forfar	7·02	...	Kincardine	4·44	..
Montrose	5·71	...	Forfar	5·86	...
Dunfermline	3·64	3·93	Perth	6·26	...
Dysart	4·10	...	Fife	3·74	...
Kirkcaldy	5·21	5·81	Clackmannan	2·39	...
Alloa	2·45	...	Stirling	2·66	...
Falkirk	2·64	...	Dumbarton	4·23	...
Stirling	4·12	4·19	Argyll	5·28	...
Dumbarton	1·81	...	Bute	4·09	...
Kirkintilloch	1·75	...	Renfrew	3·82	...
Old or West Kilpatrick	2·80	...	Ayr	3·80	...
			Lanark	2·70	...
Eastwood (Landward)	3·11	...	Linlithgow	2·62	...
			Edinburgh	3·78	...
Port-Glasgow	3·86	...	Haddington	5·05	5·13
Ayr	4·83	...	Berwick	4·85	...
Cambusnethan	2·99	...	Peebles	5·30	...
Dalziel	2·29	...	Selkirk	5·11	5·46
Kinning Park (Landward)	1·76	...	Roxburgh	6·68	...
			Dumfries	5·65	...
Hamilton	2·48	...	Kirkcudbright	4·65	...
New Monkland	2·36	...	Wigtown	4·20	...

	Registrar-General.	Corrected.		Registrar-General.	Corrected.
Mainland Rural Districts—			*Mainland Rural Districts*—contd.		
Caithness	5·49	5·84	Edinburgh	4·13	4·95
Sutherland	4·49	4·61	Haddington	4·25	5·59
Ross and Cromarty	5·21	5·24	Berwick	6·40	6·40
Inverness	4·98	5·39	Peebles	4·68	5·07
Nairn	8·77	9·73	Selkirk	4·29	6·60
Elgin	5·78	5·96	Roxburgh	6·65	7·05
Banff	6·48	6·63	Dumfries	6·49	6·70
Aberdeen	5·29	5·37	Kirkcudbright	5·18	5·84
Kincardine	4·32	4·54	Wigtown	6·52	6·67
Forfar	6·87	7·73			
Perth	5·34	5·71			
Fife	5·05	5·61			
Kinross	5·06	5·96	*Insular Rural Districts—*		
Clackmannan	5·12	5·51			
Stirling	3·21	3·90			
Dumbarton	6·26	7·37	Shetland	2·91	3·73
Argyll	4·98	5·53	Orkney	4·91	5·32
Renfrew	4·03	4·40	Ross and Cromarty	3·20	...
Ayr	2·95	3·15	Inverness	2·93	...
Lanark	3·78	4·18	Argyll	4·55	...
Linlithgow	3·50	4·48	Bute	7·61	...

Taking a broad view of these figures, it will be seen that the percentage varies from 1·76 in Kinning Park, a suburb of Glasgow, and 1·75 in Kirkintilloch, to 9·73 in the rural districts of Nairnshire. The differences cannot be due to food, as they are too widespread: they cannot be due to urban life, since many of the towns have the lowest mortality.

One point may also be mentioned at once as controverting the very generally accepted idea that the proximity of tall trees has some connection with cancer. It will be seen that the rural districts of

Orkney have a mortality above the average, amounting to 5·32, and as there is only one tree of any size in Orkney, which is looked upon as a curiosity and is situated in the centre of Kirkwall, it is obvious that the tree theory falls to the ground.

In view of these tables, I have motored over practically the whole of Scotland in the endeavour to find any clue to these pronounced differences.

On examining the COUNTIES, none of the ordinary theories which have been put forward, such as proximity to rivers and flooded districts, seemed applicable; but one thing has impressed me very strongly, viz. *that those where the death-rate was low were comparatively flat, or at most had low, swelling, undulating hills, with houses built on their sides, whereas those where the mortality was high were intersected with gulleys and valleys, with the houses as a rule situated in the hollows.*

To take, for example, the county showing the highest death-rate in Scotland, viz. the rural districts of Nairn, with a mortality of 9·73: the inhabited part of this county is largely made up of deep valleys with wooded sides, and the houses in the hollows. As one traverses it from south to north, however, about four miles from the sea the land slopes down to an almost flat stretch of country, at the extremity of which is the town of Nairn, where the mortality drops, as will be seen, to 4·11.

A very similar case is that of Dumbartonshire, which has a mortality of 7·37. The county itself is very rough and hilly. The town, on the other hand, is situated on a wide flat beside the Clyde. As the *Ordnance Gazetteer* says, its site is "a low flat plain." The mortality figure of the town is only 1·81, as compared with the 7·37 of the entire county.

Other instances might be given, but it is dangerous to draw equally accurate inferences from the mortality figures of any but the principal towns and the large town districts. One may generalise on the configuration of a county after having traversed it in several directions. The small town districts, on the other hand, are generally made up of several little villages spread over the whole county and occupying sites of a very diverse nature. In the case of these principal towns and large town districts, however, I have found a most interesting set of conditions, and feel justified in saying that I have practically proved that the situations have a marked connection with the percentage of cancer deaths.

I have taken all of the principal TOWNS AND LARGE TOWN DISTRICTS except Montrose, the situation of which is exceptional, and have grouped them, after careful consideration and in most cases personal examination, into four classes of sites, viz. the towns lying in a cup or hollow; the towns occupying a flat site and with comparatively flat surroundings; the towns on distinctly steep or hilly sites; the towns built on gentle slopes. The results are appended. After each town its corrected percentage of cancer deaths as shown by Dr. Aitchison Robertson is given, and in order that my own classification may have some proof, I have printed opposite each a description of the site as given in the *Ordnance Gazetteer* for Scotland. This will enable those who are not familiar with the districts to check my grouping. The words printed in italics are taken from the *Ordnance Gazetteer*. Any remarks in ordinary type are my own.

TOWNS LYING IN A HOLLOW AND SHOWING A HIGH CANCER DEATH-RATE.

FORFAR.	7·02.	*The town stands 200 feet above sea-level in a kind of basin formed by the surrounding slopes.*
GALASHIELS.	5·19.	*The town sends off-shoots, extending up the slopes to the adjacent hills. It is flanked and overlooked on the one side by Meigle Hill* (1387 *feet*) *and Gala Hill, and on the other side Buckholm and Langlee Hills.*
HAWICK.	5·27.	*The town is in a basin.*
KIRKCALDY.	5·81.	This town lies in a cup, and, at the same time, on a steep slope. *The main street stretches like a skeleton backbone that has been twisted with spinal curvature, while side streets and closes lead down to the shore or back to the villas which adorn the upper part of the town.*

Inverness.	5·02.	*On all sides, except the sea margin, the site is hemmed in by rising grounds.*
Aberdeen.	4·53.	This city lies in a hollow at the mouth of the River Dee.
Ayr.	4·83.	*Its site is low ground, screened all round by gently rising heights which form a great natural amphitheatre.*
Perth.	4·29.	*The site of the town is a flat-bottomed hollow environed with rising ground overlooked by an amphitheatre of well-wooded hills.*
Arbroath.	4·76.	*Its site is a little plain engirt on the land side by eminences of* 100 *to* 200 *feet.*
Dumfries.	4·61.	The town lies in a hollow, and on an uneven site. *The site extends about a mile from north to south parallel to the river, rises steeply from the banks at the north end.*

Towns on Distinctly Steep or Hilly Sites Showing a Percentage Slightly Above the Average.

Edinburgh and Leith.	4·03 and 4·11.	These sites are notoriously hilly.
Stirling.	4·19.	
Dundee.	4·09.	
Dysart.	4·10.	It is interesting to compare the mortality figures of Dysart with that of Kirkcaldy, of which it is almost a suburb. The hilly nature of the site is almost similar, but Kirkcaldy lies curved round a cup or bay, and this, I believe, causes its higher figure.

Towns on Slopes Showing a Percentage Below the Average.

Eastwood.	3·11.	Near Glasgow, and contains the town of Pollokshaws. *The surface westward declines to* 50 *feet above sea-level, rising to* 167 *feet,* 170 *feet,* 221 *feet, and* 302 *feet.*
Cambusnethan.	2·99.	Contains the towns of Wishaw, Newmains, Coltness, etc. *The tract along the Clyde sinks to less than* 100 *feet above sea-level ; the surface thence has a general eastward rise.*
Kilmarnock.	3·80.	*The site slopes gently to the south.*
Dunfermline.	3·93.	*Its site is variously flat and sloping.*
Hamilton.	2·48.	*The town is situated in the midst of a pleasantly diversified ridge, sloping on the whole to the east, north-eastward.*

Paisley.	3·02.	*Part of the site of the burgh is a gentle, hilly ridge. Part is the north side of a similar ridge, and the rest is partly low ground lying between and around these ridges.*
Greenock.	3·12.	*The shore is fringed by a strip of level ground; beyond, the surface is hilly.*
Port-Glasgow.	3·86.	*There is a flat strip along the Clyde from 13 to 20 feet above sea-level, and from this the ground slopes rapidly up.*

Towns Occupying a Flat Site and with Comparatively Flat Surroundings Showing a Mortality much below the Average.

Dumbarton.	1·80.	*Its site is a low flat plain.*
Kirkintilloch.	1·75.	Ditto.
Alloa.	2·45.	*The carse lands around it consist of alluvial flats.*
Peterhead.	2·79.	Surrounded by a wide tract of flat country.
Glasgow.	2·98.	*The site, especially towards the east and south, is very flat, as it also is on the north along the side of the river. Nowhere in these districts is it more than a few feet above the level of the spring tides.*
Kinning Park.	1·76.	A flat, low-lying suburb of Glasgow.
Govan.	2·08.	Ditto. *Along the Clyde is low and flat, varying in height from 19 to 24 feet at Govan burgh.*
Rutherglen.	2·14.	Ditto. *The portion of the parish along the Clyde is from 30 to 40 feet above sea-level.*
Falkirk.	2·68.	*The site is partly a gentle hillside, partly low level ground.*
New Monkland and Coatbridge.	2·36. 2·69.	*The dorsal ridge that runs through it from end to end ascends from so broad a base so gently and continuously as nowhere to form any height, which, properly speaking, can even be termed a hill.*
Dalziel.	2·29.	*Sinking to less than 100 feet above sea-level, it forms in the centre, and towards the south-east, a flattish ridge or low plateau.*
Old Kilpatrick.	2·80.	*Low flat ground along the Clyde.*

From these groupings it will be seen that the towns lying in a cup have by far the highest cancer mortalities, while those on a level site with level surroundings show the lowest percentage. Those on hilly sites are slightly higher than those on sloping sites.

Take another instance from England as typical of many.

The great fluctuation in the cancer mortality of different registration districts in any one county is very remarkable. For example, the North Riding of Yorkshire shows the following results in comparing the cancer deaths with those from all other causes, and in dealing with a part of the country like this such is really the best way of getting at the truth of the matter.

Registration Districts.	One in	Per cent.	Registration Districts.	One in	Per cent.
North Riding Average	**17·19**	**5·81**	Guisborough	13·48	7·41
			Middlesborough	25·87	3·86
Scarborough	10·63	9·40	Stokesley	27·82	3·58
Malton	14·60	6·85	Northallerton	15·6	6·41
Easingwold	27·40	3·65	Bedale	24·40	4·09
Thirsk	15·81	6·32	Leyburn	6·66	15·01
Helmsley	7·39	13·53	Aysgarth	11·50	8·69
Pickering	11·53	8·67	Reeth	39·00	2·56
Whitby	12·70	7·87	Richmond	19·75	5·06

One is at once struck by the high proportion of cancer deaths in the Leyburn registration district. As this district is made up of different kinds of country, and includes three small towns of exactly similar proportion, viz., in each case between 950 and 1000, I thought it worth while to spend a day going over the actual register of deaths in order to localise the individual cancer deaths for the last ten years. I could only get a rough map from a local guide-book, but the results are very instructive. Each cross represents a death from malignant disease in the town, village, or farm nearest it. In the Leyburn and Middleham neighbourhoods it will be

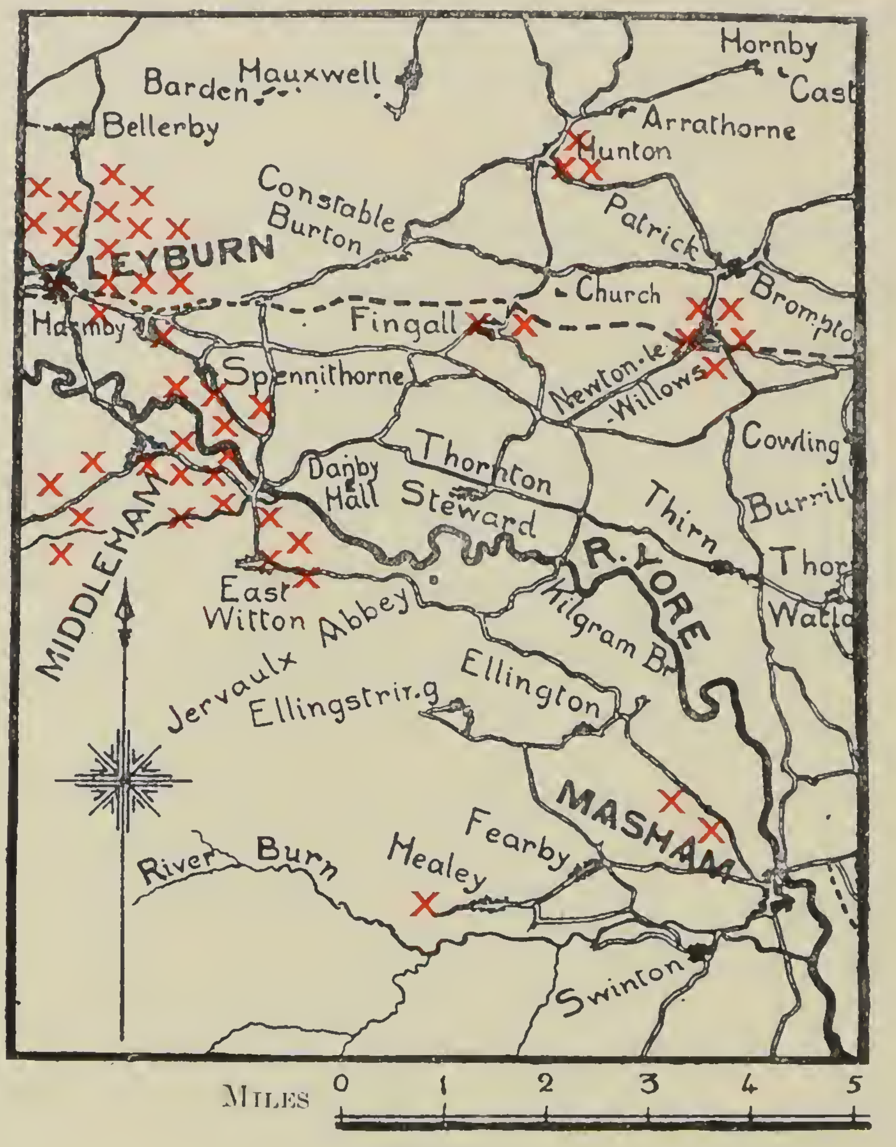

Fig. V.

seen that cancer is very common, while in the Masham neighbourhood, which is under the Leyburn registration district, cancer is extremely rare.

In Masham town the registers only revealed 2 cancer deaths in 10 years.

In Leyburn town 15 cancer deaths were recorded. In Middleham 12 deaths, while the small village of East Witton alone shows 4 deaths.

On comparing the sites of these places we find that—

Masham is built round a large flat square market-place, and has level surroundings.

Leyburn is built down a street with a steep gradient of 1 in 12.

Middleham is also built down a sharp slope, the gradient of its main street being given in the contour road book as 1 in 14.

East Witton slopes steadily down a long narrow village green, the end of each house being about 4 feet below the one above it.

Many other instances might be given, but the above is typical of what an examination of the actual registers reveal when each death is "posted," as it were, to its actual locality.

In dealing with this subject, when the situation of a town seems to have so marked an influence upon its cancer mortality, it would be even more valuable to discover whether there were certain portions of the larger towns more liable than others. There has been a most interesting piece of work done by Behla[1] on his own town of Luckau in Germany which seems to me to bear very strongly upon the view which I have sought to bring forward. In the course of twenty-two and a half years' practice in this town of Luckau he noticed that while he had never met with a case at all in the Sandoer suburb, in the Kalauer there was hardly a house which had not had several cases in it. In order to show the lie of the ground and the relative positions of the two portions of the town, I have had it specially photographed. The Sandoer portion, in which no case had occurred in the twenty-two years, lies on the height; the Kalauer lies *in the hollow.* The following is a translation of a portion of Behla's paper:—

> I have been practising for twenty-two and a half years in Luckau—since October 1875. It numbers about 5000 inhabitants, including some 500 inmates of the female prison. The number of inhabitants has remained stationary to the present day, and in particular the Kalauer Vorstadt has retained the same number of houses.
>
> In the course of my practice it struck me that cancer, *which was never to be met with at all in the Sandoer Vorstadt*, but occurred not

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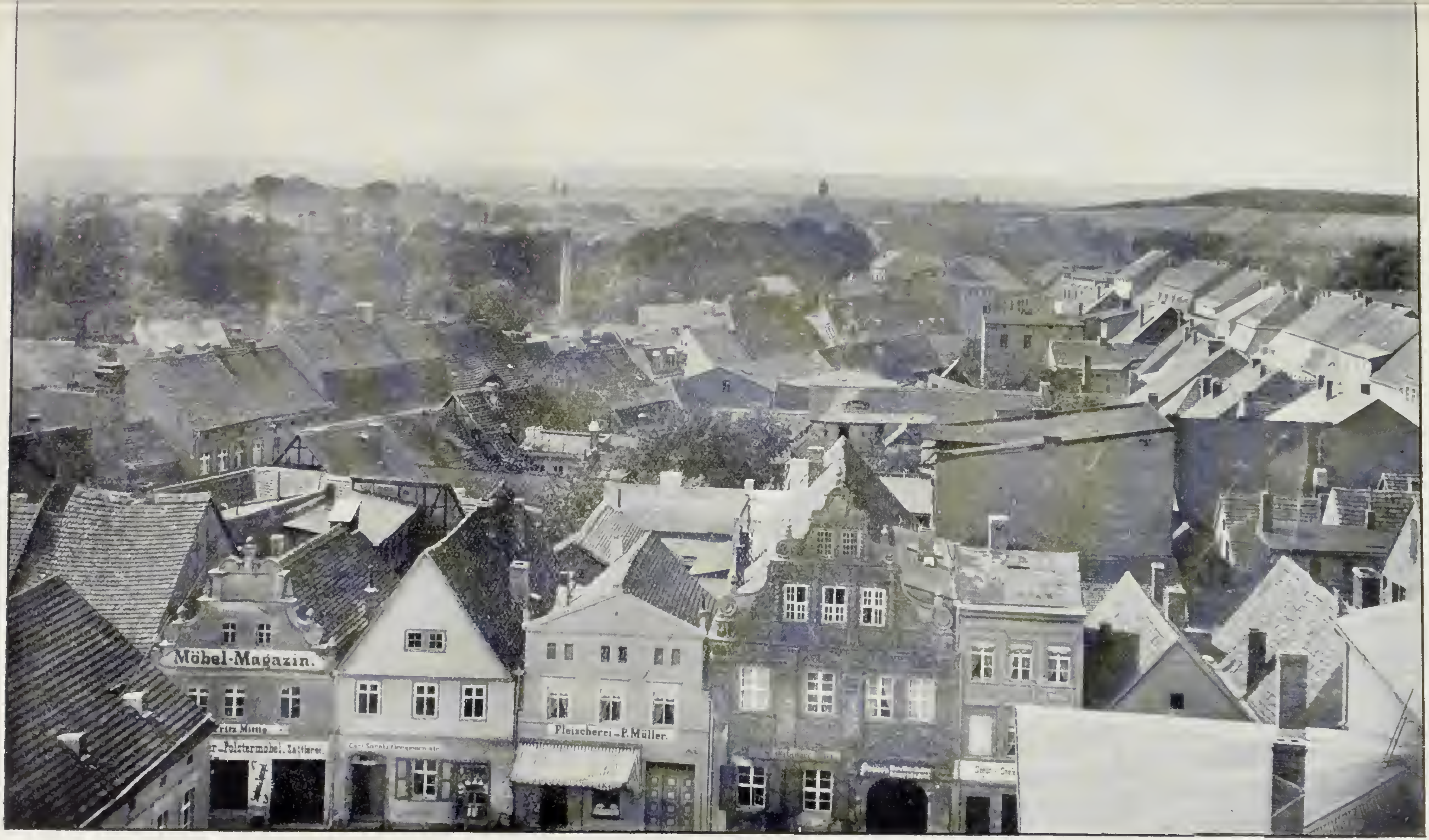
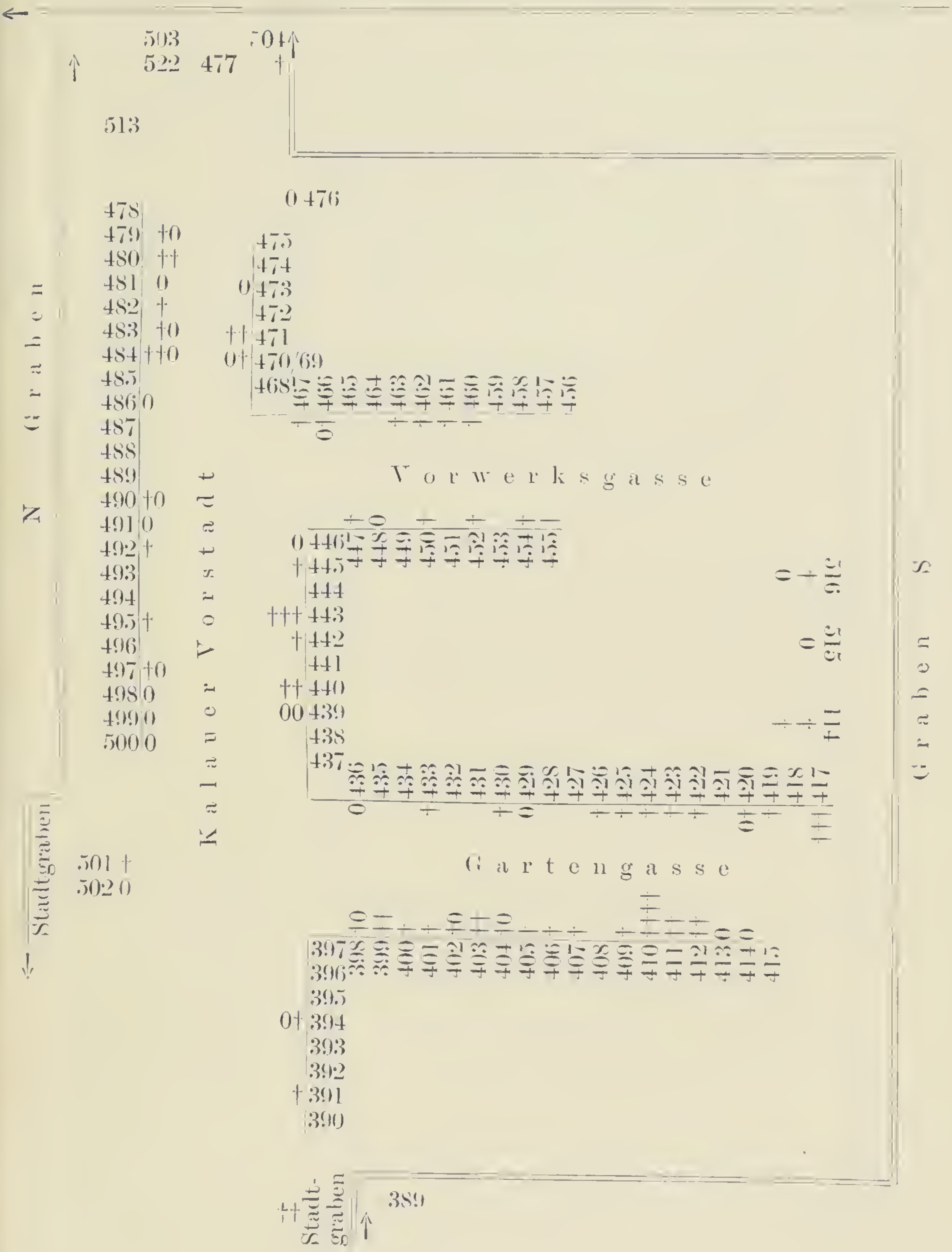
[1] *Cent. f. Bakt.* 1898, and *Zeits. f. Hygiene*, 1898.


Möbel-Magazin.
Fritz Mittig
Polstermöbel. Sattlerei.
Fleischerei - P. Müller.

Luckau.

Luckau (Kalauer Vorstadt).

Berste-Fliesz O



infrequently in the town itself, was very common in the Kalauer Vorstadt, a circumstance to which I felt constrained to devote special attention. Reckoning for the whole town, only one death out of every 25 to 30 was found to be due to cancer, whereas the proportion in the Kalauer Vorstadt was an exceedingly striking one. From October 1, 1875, to April 1, 1898, 663 deaths occurred in this part of the town, 73 of these being due to cancer; we have therefore already on an average 1 death from cancer in every 9—a very high proportion in comparison with that of other places.

For greater ease in studying the matter, I have marked each case of cancer in the accompanying plan according to the house in which it occurred. The numbering of the houses runs from 387 to 516, and I have designated them in the plan with these numbers in their order. The houses in which cases of cancer occurred between October 1875 and April 1898 are distinguished by a cross.

In the more recent records a number of cases occur where the cause of death is stated to have been, primarily, cancer. These also I have entered in my plan of the Kalauer Vorstadt, marking the houses where they occurred with an O.

A glance at the plan shows us that by far the greater number of houses have been visited by cancer.

We may note that just in the Gartengasse, and particularly on the west side, cancer has made great inroads; it is a veritable "cancer street." This cannot be pure chance. There must be some cause; some particular infective agent must be responsible for this prevalence of cancer in one small district.

In Luckau, therefore, we find that cancer is very prevalent in the hollow, and to further illustrate the relationship of the lie of the ground to malignant disease in the case of an even more restricted district, I annex a plan given in Murphy's *Surgery*, Fig. VI., illustrating a cancer district which Mr. Murphy had personally investigated, and on the strength of which he suggests that the condition is infectious. This

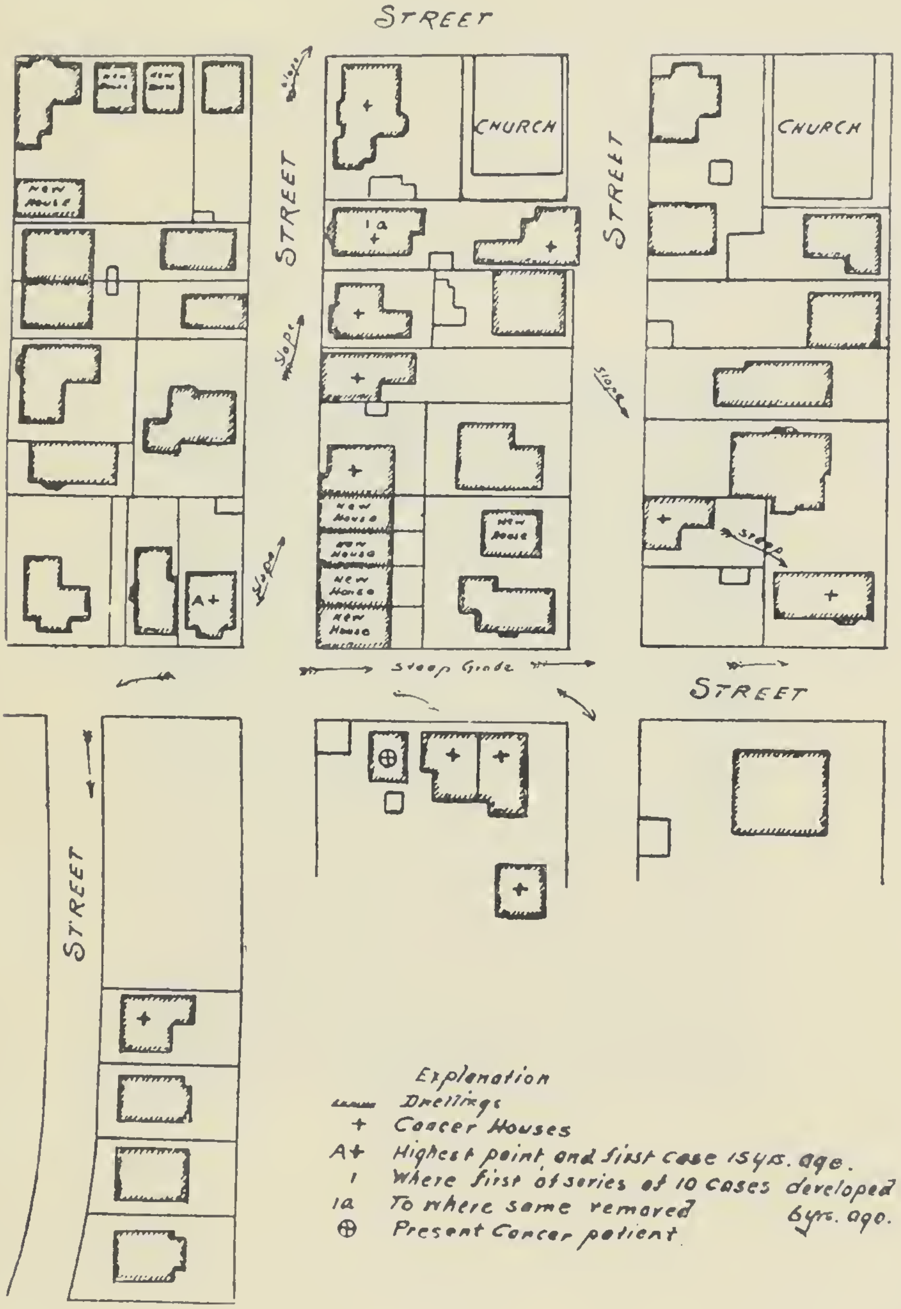


FIG. VI.

plan is worthy of most careful study, as the author has indicated the slope of the ground by arrows. If these arrows are followed, they will be found in a most remarkable way almost to point to the houses in which cases have occurred. The first case occurred in a house at the top, but it is a corner house, and it has often been claimed that in corner houses cases are very common; all the others follow exactly the contour lines of the falling gradients.

Finally, I reproduce below an old photograph of a

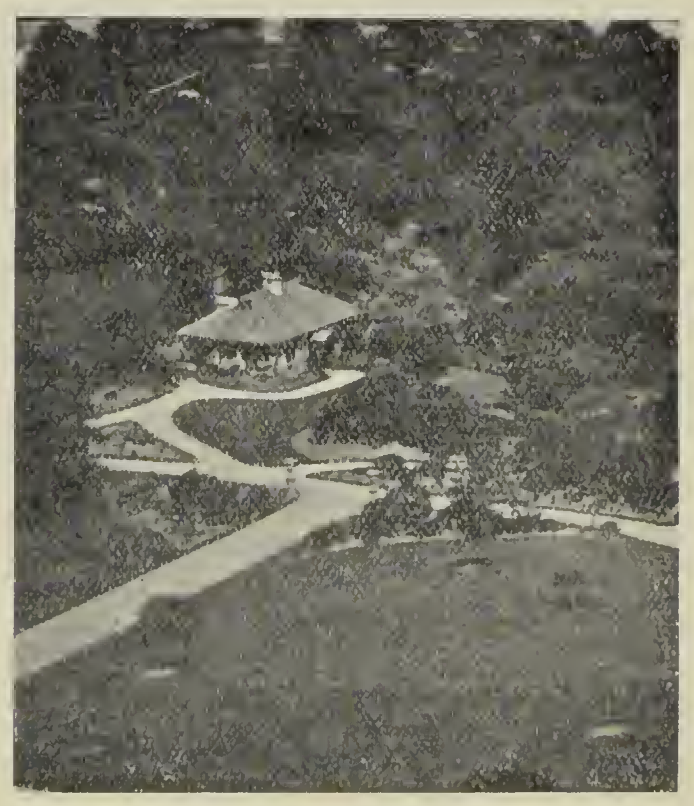


FIG. VII.

house in my own district which had ultimately to be pulled down owing to the great number of deaths from cancer which occurred in it. It lies, as will be seen, at the bottom of a steep tree-clad slope on two sides of the cottage.

CHAPTER IV

THE INFLUENCE OF FUEL

If, then, the lie of the ground seems to have a mysterious influence on the local incidence of cancer, how can this be explained?

I may say at once that I am convinced it can only be explained in RELATION TO THE ELIMINATION AND REMOVAL OF PRODUCTS OF COMBUSTION FROM THE HOUSES OR FROM THEIR NEIGHBOURHOOD. If soot or some of its ingredients can cause epithelioma in chimney-sweeps and coal tar bring it on in coal tar workers who work with an actual material which induces the disease, is it not reasonable to expect that inhabitants of a district where the products of coal combustion are imperfectly removed should be more subject to cancer than dwellers in a district where these are more perfectly removed?

When I first realised that the disease was more prevalent in certain districts than in others, I began to carefully examine the exterior of the individual houses in which I could discover that cases had occurred in my own neighbourhood. I disregarded cases in which the occupants had been less than three years in the house, and also those of men who went out to business all day.

For a long time I could find nothing in common between these houses, which were of all descriptions, from isolated country cottages to large suburban mansions and city flats, until it occurred to me that many of them had appliances on the chimneys, evidently designed to encourage and increase the draught. A further inquiry elicited the fact which one would have expected, viz. that in nearly all of the houses some of the rooms were smoky.

This question of the relation of chimneys and of smoke to cancer has never been previously referred to, but I believe that it furnishes one of the keys to the problem. The products of combustion in a room must either go up the chimney or out into the room. If the chimney is defective the latter result ensues. A proper chimney should carry all these products out into the atmosphere. Wherever cowls or other appliances are placed on the chimney heads it is a proof that the smoke has in that chimney a tendency to come out into the room instead of being drawn up. It must be borne in mind also that fumes may be coming out into a room although no smoke is visible.

Wherever the head of a chimney is below the level of the surrounding roofs or of the surrounding ground, the tendency is for the smoke not to rise. In this way it will often be found that the chimneys on one side of a house will not draw, while those on the other draw excellently. In the same way, on a slope, the chimneys of the houses at the top of the slope will usually be found to draw better than those on the slope itself. Trees often have the same effect as an adjoining roof or an adjoining slope, and this to my mind is the explanation of the oft-repeated suggestion that the proximity to tall trees has some connection with cancer.

I believe, indeed, that the roof level of a city has more to do with its cancer death-rate than anything else. If streets of sky-scraper buildings are alternated with rows of smaller houses, the products of combustion cannot be properly eliminated from the latter or from the district. This is the obvious reason to my mind why cancer should account for 1 death in 7 in the Strand district and only 1 death in 54 in Stepney, where the houses are all much of one height —small two-storey buildings. Although London has a flat site the benefit from this is lost by the conditions I have indicated.

I have already pointed out that Glasgow has a very low cancer mortality, although it is a large industrial centre. Glasgow has not only a flat site, but its roof line is phenomenally flat and level. As is shown in the accompanying illustration, all the houses in a district are of the same height. Stepney has also the lowest death-rate from cancer in London, and is nearly as low as Glasgow. If its roof line be compared with that of the Strand district the difference will be at once apparent.

Now too much may seem to have been made of this point, but there is no gainsaying the fact that in tropical countries where there are no chimneys the disease is almost unknown. In Jamaica, for example, where there are no house-heating chimneys, and where all cooking is done outside, the cancer death-rate is almost inconceivably small, viz. 1·6 per 10,000 living.[1]

In the same way the cancer mortality of the Northern States of America is double that of the Southern States.

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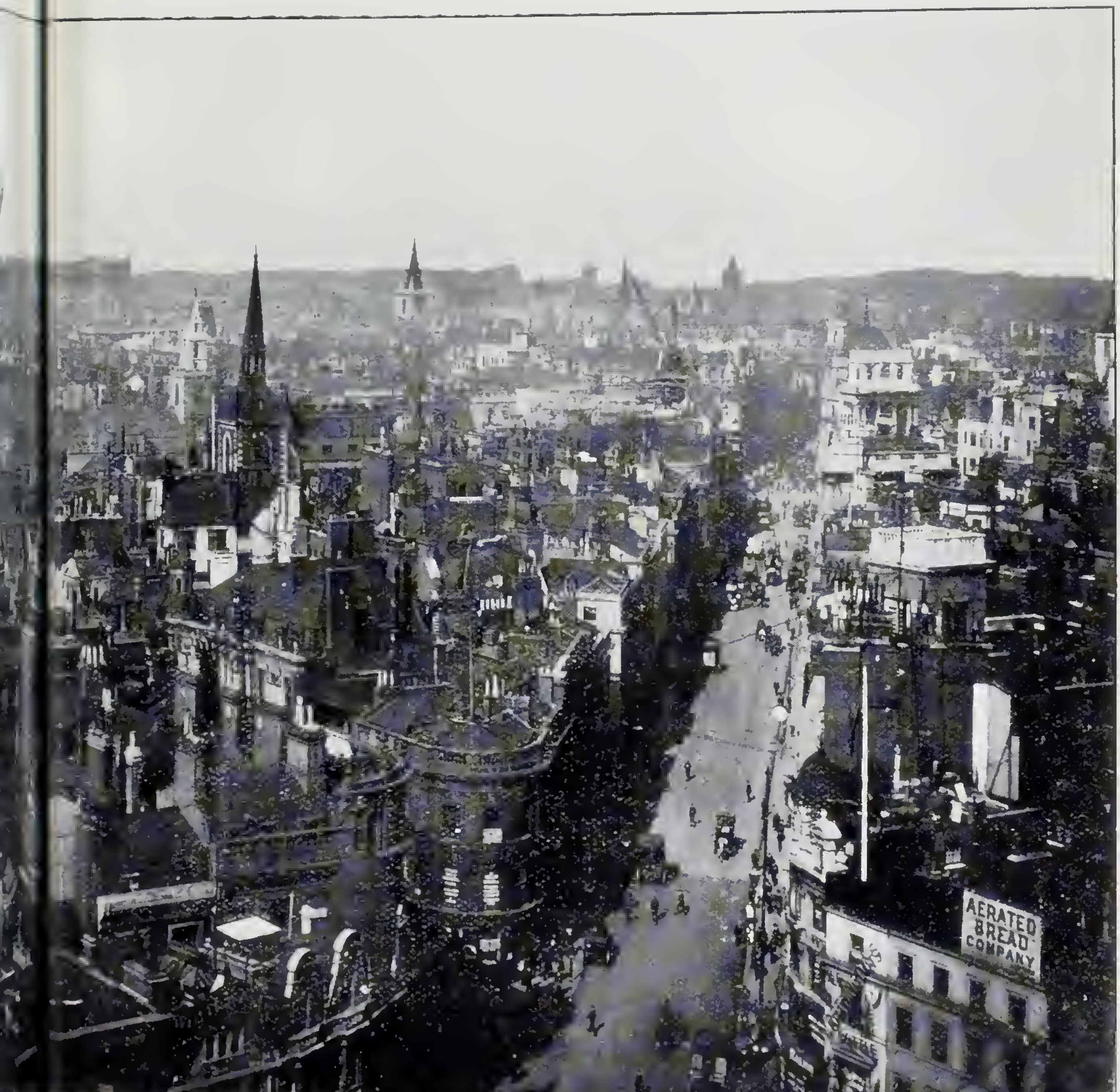
[1] This low death-rate was lately disputed by a well-known authority on the ground that it was unreliable, since only a proportion of the deaths were medically certified. I have, however, had the opportunity of discussing it personally with the Registrar-General of Jamaica, who states that exactly 71 per cent. of the deaths in Kingston are medically certified. The deaths from carcinoma in Kingston for 1908 were 9; from sarcoma, 1; from malignant disease not otherwise defined, 8. The total deaths in Kingston for the same period were 1959, so that *cancer accounts for only 1 death per 100 in Kingston.*

p. 70. A District in London with a Death-Rate from Cancer of 1 out



ERY 7 Deaths from all Causes. Note the Irregular Roof Line.

Three Views of the Roof Levels in Stepney, whe

HER ANCER ONLY ACCOUNTS FOR 1 DEATH IN 54.

A District in Glasgow with a Death-Rate from Cancer of only 1

60 Deaths from all Causes. The Roof Line is Practically Level.

In Mexico, according to Jourdanet, it is almost unknown in the hot regions, whereas in the cool regions on the high plateaux it is frequent. My explanation of this would be that in the high plateaux they have to burn fires. In the hot districts they do not.

Roger Williams, in his interesting chapter on the geographical distribution,[1] sums up by saying that the disease seems to increase in frequency with remoteness from the Equator, and asks how the much greater prevalence of malignant tumours in temperate than in hot climates which his world-wide survey reveals can be accounted for. To my mind it is obvious. The further from the Equator the greater the necessity for artificial heat, with its concomitant products of combustion.

I was lately asked by a tea planter in India, who knew that I was interested in the subject, why his coolies who suffered from cancer, as was the case with not a few, should always have it in the penis or on the face. I suggested that they might hunker over fires, and he assured me that this is just what they do in cool weather, shutting the doors and windows of their huts and sitting crouching over and around a brazier.

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[1] *Natural History of Cancer*, p. 22.

It is a curious fact, too, that in many countries while the white population suffer severely, the aborigines, who live differently and do not warm themselves by artificial heat, are immune.

A striking case is that of the American negro. Chisholm's statistics show that before the emancipation the whites were more than twice as liable as the blacks. The planters gave their slaves wide, airy rooms, plenty of simple food, and much outdoor labour. Since the negress has lived in her own house her death-rate from uterine cancer has become 20, as against 15·7 for her white sister. In the same way the North American Indians were exempt from cancer in their primitive savage condition, but with modern civilization their comparative immunity has now passed away.

Even some of the apparent exceptions to the statement that the disease seems to increase in frequency with remoteness from the Equator seem to bear out the accuracy of my suggestion. It has been pointed out, for example, on more occasions than one that the disease is rare in ICELAND. Dr. Jefferson, who visited these islands in 1892, informed Dr. Roger Williams that the disease was then very rare. During some months' residence he never saw a case. In 1890 there were only two deaths from cancer in the whole of Iceland. In 1900 twenty-two such deaths were notified. I have taken some trouble to inquire into the conditions in Iceland, and find that until recent years no coal was used at all. The ordinary grate is still almost non-existent; stoves which burn peat or turf being generally used. Coal, however, is now being imported to some extent.

In the FÄRÖE ISLANDS, again, cancer was quite unknown until lately. Panum saw no case of it during his residence in these islands, nor could he hear of any. Davidson, in his *Geographical Pathology*, as lately as 1892 (vol. i. p. 13), says: "Here, then, we have a country from which this terrible scourge of humanity is absent."

Now, in the Färöe Islands we have a most interesting set of conditions. In Lanat's description of the "Feroe Islands," 1810 (the authority on the subject), we are told regarding the kitchens, that "they have no chimney, but on one side a few large stones laid on the floor serve as a fireplace, and some stones or bricks placed behind it prevent the wooden wall from being damaged by the fire. A square hole in the roof admits the light, and at the same time gives vent to the smoke. In rainy weather this hole is covered with a board." "It is very remarkable, as there are no chimneys in such apartments, and though the wooden walls are so near the fireplace, that fires are scarcely ever heard of. This seems to be owing to two causes: the first that the timber used for building is floated and impregnated with salt water. The second is that *nothing is burned here but turf.*"

As to the present conditions, I have lately been in correspondence with Mr. Coates, the British Consul, who has kindly given me some details. "Cancer," he writes, "is not now an altogether unusual disease in the Färöe Islands. The Färöese use open hearths and stoves, in which turf is generally used as fuel; *some coal is now, however, being burnt at the larger towns.*" The conditions seem to be similar to those of the cottars in the Lewes, where cancer is also almost unknown, and where the open turf hearth is the general rule.

An even more striking case is that of GREENLAND, where until lately cancer was unknown. The best monograph on this subject is by Gustav Meldorf—"Uber das vorkommen von Geschwülstein bei der Bevölkerung in Gronland" (*Nord. Med. Arkiv*, 1907).

As Meldorf states: "The assumption that cancer occurs extremely rarely or not at all among the natives of Greenland depends upon the circumstances that the four doctors who on previous occasions have dealt with the occurrence of cancer in Greenland, viz. C. Lange, Chr. v. Haven, M. Hastrup, and H. Kiaer, have not themselves had such cases to register and have not been able to find such definitely proved cases in the reports from the district doctors. It was only in the year 1904 that Bertelsen published definite information about the occurrence of cancer in Greenland."

Carl Lange writes: "Six persons died, according to Lindorff's frequently mentioned statistics, from cancer, but we have nevertheless no absolute certainty of the correctness of the diagnosis. As this disease is never mentioned by the district doctors, and as I have never myself observed any case of it, the question as to whether cancer occurs in Greenland at all must be left open in the meantime. In any case it must be extremely rare."

Chr. v. Haven observes: "In any case I believe that ulcera maligna and cancer practically never occur, which is particularly peculiar with regard to the mouth, as a large number of the population, men, women and children, smoke strong tobacco in little clay pipes throughout the entire day."

M. Hastrup mentions: "The reported cases of malignant tumours in Greenland must in any case be regarded as so doubtful that the occurrence of these growths has to be regarded as altogether uncertain. Personally I have never observed cancer in any form whatsoever in North Greenland, neither have I found this disease mentioned in the reports of the district doctors."

H. Kiaer mentions: "With regard to new growths I have never observed any sure cases of cancer."

As mentioned, Bertelsen points out for the first time, in a printed report, the undoubted occurrence of cancer in Greenland. But he at the same time mentions that the diagnosis had not been verified by microscopical examination.

The paper goes on to describe and deal with practically every known case which has been met with in the last year or two, and undoubtedly cases are now occurring, although very rarely. Now in Greenland until quite lately fireplaces were unknown, as Nansen says in *Eskimo Life*, pp. 81 and 82.

"In Greenland houses of the old style there are no fireplaces; they are warmed, as well as lighted, by *oil lamps*, which burn day and night.

"The lamps are large, flat, open saucers of soapstone. They are of semicircular form, and along the straight side lies the wick, which is formed of dry moss, or, nowadays, of cotton. These lamps rest on a wooden stand, and are placed on a little table or raised place in front of the sleeping-bench. There is generally one of these lamp-tables to each family. If several families dwell in one house, there are many lamps, for each family has at least one burning, and, as a rule, more.

"In former days, food used to be cooked over these lamps in soapstone pots, which hung from the roof. The preparation of food, like every other business of life, of course went on in the common room.

"So it is to this day on the east coast. On the west coast, modern civilisation has effected a change, in so far that food is generally cooked in a special room with a fireplace, built on to the side of the passage leading into the house."

Nowadays we are so used to the combustion of coal that we think nothing of its smoke and sooty deposits. This was not always the case, however.

That the fuel was received at first with disfavour appears from the fact that in the reign of Edward I. the nobility and gentry made a complaint to the king objecting to its use, on the ground of its being a public nuisance. By the middle of the seventeenth century the use of coal was becoming more general in London, chiefly owing to the scarcity of wood, and its effects upon the atmosphere of the town will be inferred from a proclamation issued in the reign of Elizabeth, prohibiting its use during the sitting of Parliament, for fear of injuring the health of the knights of the shire. About 1649 the citizens again petitioned Parliament against the use of this fuel on account of the stench; and about the beginning of that century "the nice dames of London would not come into any house or roome when sea-coales were burned, nor willingly eat of meat that was either sod or roasted with sea-coale fire" (*Stow's Annals*).

An open hearth with a hole in the roof is a totally different condition from that of the ordinary grate with in some cases fifty or one hundred feet of chimney between it and the open air. Custom has reconciled us to what our ancestors took serious exception, but I am convinced that we have had to pay the price in an increased susceptibility to malignant disease from the products of coal combustion by means of the grate and chimney. Among the products of that combustion are gases which are heavier than air, and are very apt to come out into the air of the room under the chimney conditions which I have mentioned. Even although the smoke may seem to be drawn up, it does not follow that they are drawn up.

In addition, we have the accumulation of soot and coal tar in the chimney. In many rooms with windows and doors closed the only possible source of ventilation is through this filthy, soot-lined funnel. When the situation of a house is such that the wind actually *blows* its products down into the room the circumstances are infinitely worse, and if soot and coal tar are conducive to cancer it is hardly to be wondered that it occurs more frequently under such local conditions.

I have recently undertaken an investigation which seems to me to furnish strong proof of the facts (1) that the lie of the country has a marked effect on the cancer death-rate; and (2) that cancer is due to some product of combustion of coal. In order to confirm and amplify the results which I had previously obtained, I was anxious to make a minute investigation of the cancer incidence of Nairnshire for the following three reasons:—

(1) Because, as already stated, it is shown by the Registrar-General to have the highest death-rate from cancer in Scotland in its rural districts, with a normal death-rate in the town.

(2) Because it contains within its borders all kinds of country—hilly, sloping, and flat.

(3) Because it is almost unique in regard to the

fuel used—coal being burned within a mile or two of the railway, and nothing but peat beyond.

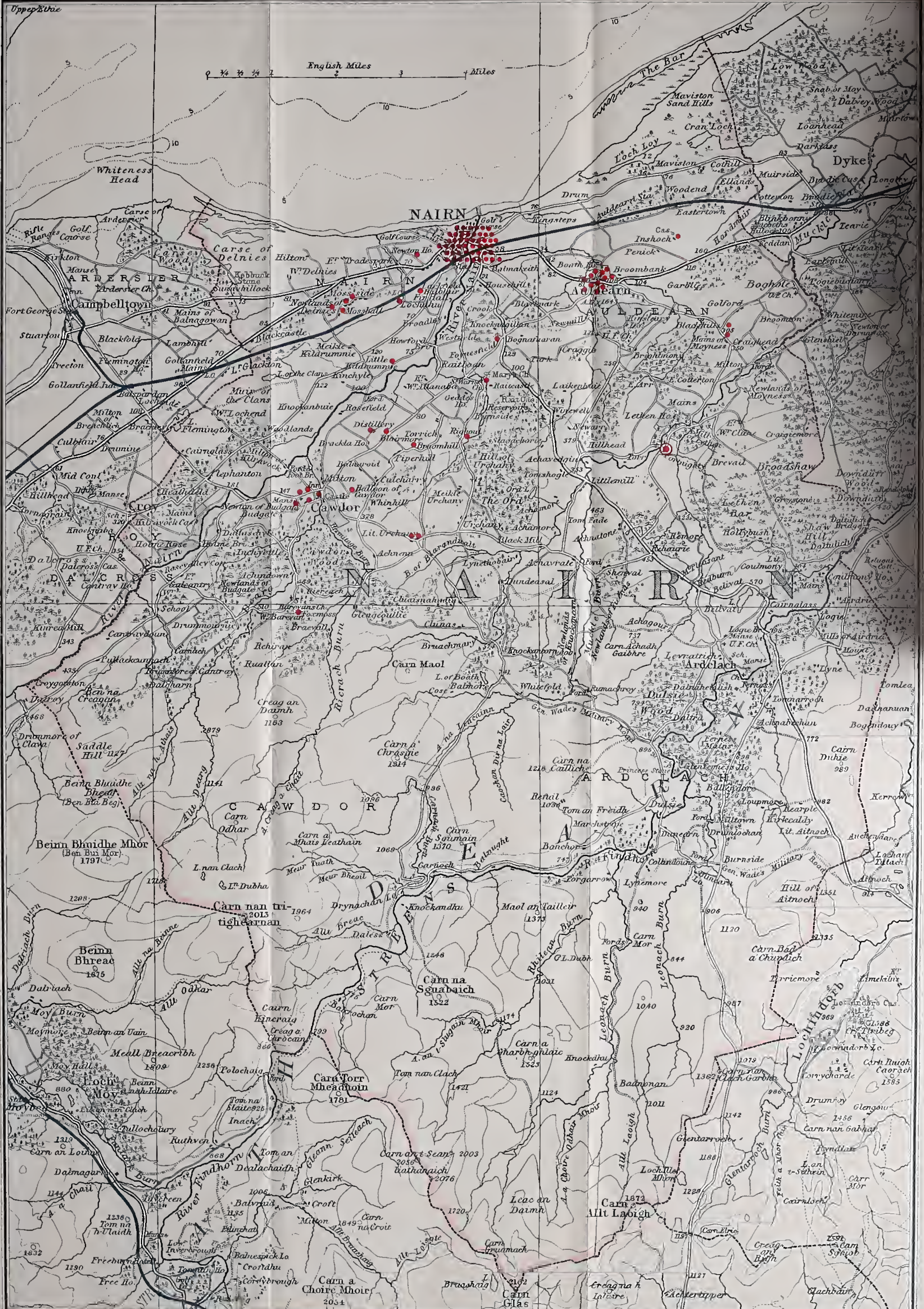
This investigation I had the opportunity of carrying out by personally going over all the registers of deaths in Nairnshire, noting the individual deaths from cancer for the last ten years, and marking in red on an Ordnance map the place of residence of each sufferer. A copy of this map is annexed.

The county is divided into four registration districts, and the total population is just under 9000. Of this population, as nearly as can be calculated, 5800 is in the town district of Nairn itself, and 1000 each in the three remaining districts of Cawdor, Auldearn, and Ardclach.

Now a careful scrutiny of the death registers revealed the surprising facts that the cancer deaths for each of these districts, including sarcoma and rodent ulcer, for the last ten years are as follows:—

Nairn,	57	cancer deaths	out of a total of	1056	from all causes.
Cawdor,	13	,,	,,	120	,,
Auldearn,	15	,,	,,	168	,,
Ardclach,	1	,,	,,	105	,,

In the Ardclach district, which covers about 100 square miles, therefore, in the last ten years



Inverness

John Bartholomew & Co. Edin.

there was only one death from cancer, and that was a rodent ulcer in a patient aged 81.

Even this case was not in the Ardclach district proper, but at Fornighty, on the verge of the Auldearn district. It is marked with a red circle on the map.

The first thing which strikes one in this cancer map of Nairnshire is that although the county has the highest mortality figure from cancer in Scotland —8·77 according to the Registrar's figures for 1895, 1896, and 1897; and 9·73, according to Dr. Aitchison Robertson's corrected figures—the cancer deaths for the last ten years are confined to a definite area, and the rest of the county is entirely free.

The second point is the relationship of the lie of the ground to this cancer death-rate. The registration district of the town of Nairn is flat, and lies a little above the sea level. A mile or so inland the ground slopes rapidly up to the 500 or 600 feet level, and it is on this slope and immediately at the foot of it that the highest cancer death-rate occurs —in the two registration districts of Cawdor and Auldearn, which respectively lie on the west and east slopes of this declivity. The Ardclach registration district covers the rest of the entire county, a tract of country of about 100 square miles.

Although the town of Nairn seems to have a high mortality figure from cancer, looking to the number of spots on it, it must be remembered that the bulk of the population is centred there, and that its 57 cancer deaths were out of a total of 1056 from all causes, or a mortality of 1 death in every 19, which is not excessive.

The Cawdor and Auldearn districts, on the other hand, lying on the slope and in the hollow below it, show 28 cancer deaths in the ten years out of a total of 288 deaths from all causes, which is equal to 1 death in every 10 from all causes—a very high ratio indeed, and almost double that of the flat district.

The most striking point of all, however, remains. How are we to account for the fact that in this county, which has been shown by statistics to have the highest death-rate from cancer in Scotland, there is a tract of about 100 square miles, mountainous, with houses on slopes and in hollows, inhabited by 1000 people, eating and drinking and smoking in the same way as their immediate neighbours, engaged in much the same pursuits, and yet so free from cancer that the nearest approach to it is one case of rodent ulcer? To my mind, it is explainable on one ground and on one ground only, and that is that its inhabitants burn peat and nothing else.

In the town of Nairn nothing is burned but coal. The Auldearn district is also one in which coal is the fuel used. In Cawdor, coal and, to a slight extent, wood. In the rest of the county peat is abundant, and as no railway traverses it the inhabitants are compelled to rely on the peat bogs.

Now peat as a rule contains very little sulphur, and this result corroborates the views which I have expressed in Chapter II.

At the same time I was urged, not unwillingly, to undertake a similar investigation on another county as a check on my previous results.

For several reasons I thought that Orkney would be the most suitable county. Its cancer mortality is slightly above the normal, the average for the whole of Scotland being 4·023, while that of Orkney is 5·32.[1] It is a county with practically no manufactures to confuse the issues, whose inhabitants are mainly farmers or fishermen; but what appealed to me most was the fact that it is split up into many islands, on some of which nothing is burned but peat and on others nothing but coal, as the peat bogs have been worked out.

The first step in the investigation was of course to get the address of every patient who had died from cancer in these islands during the last ten years, and by the kindness of the Registrar-General for Scotland I was given the privilege of personally going over all the Orkney death registers for the last ten years and noting these addresses. I found that in all, for the ten years from 1902 to 1911, the number of cancer deaths, including sarcoma and rodent ulcer, amounted to 286 out of a total of 4051, or an average of 1 death out of 14 from all causes. The proportion of cancer deaths to those from all causes in the various registration districts and islands, however, varied very markedly, as will be shown by the following table. It is a curious and almost incredible fact that in North Ronaldsay, although 56 deaths from all causes were registered in the ten years, the cause of death was always given as "unknown; no medical attendant." This explains the omission of North Ronaldsay from the table.

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[1] *Edin. Med. Journ.*, 1903, vol. i. p. 23.

Table showing the Proportion of Cancer Deaths to Deaths from all Causes in the Registration Districts of Orkney.

Birsay . . .	1	cancer death	in every	8	from all causes.
Deerness . .	1	,,	,,	15	,,
Eday and Pharay .	1	,,	,,	11	,,
Evie and Rendall .	1	,,	,,	14	,,
Firth . . .	1	,,	,,	13	,,
Flotta . . .	1	,,	,,	20	,,
Harray . . .	1	,,	,,	10	,,

Holm	1	cancer death	in every	20	from all causes.
Hoy and Graemsay	1	,,	,,	25	,,
Kirkwall	1	,,	,,	17	,,
Orphir	1	,,	,,	18	,,
Papa Westray	1	,,	,,	9	,,
Rousay and Egilshay	1	,,	,,	28	,,
St. Andrews	1	,,	,,	11	,,
Sanday	1	,,	,,	9	,,
Sandwick	1	,,	,,	11	,,
Shapinshay	1	,,	,,	7	,,
South Ronaldsay	1	,,	,,	22	,,
Stromness	1	,,	,,	27	,,
Stenness	1	,,	,,	42	,,
Stronsay	1	,,	,,	22	,,
Walls	1	,,	,,	20	,,
Westray	1	,,	,,	16	,,

The preparation of a map showing the exact location of each death, similar to that of Nairnshire, has been a very difficult undertaking, as many of the names are not given on the Ordnance map, and involves correspondence with local people in order to attain accuracy. In the meantime, however, I have written every parish minister in Orkney asking details regarding the kind of fuel used in his parish, and cannot thank these gentlemen sufficiently for the trouble they have taken in giving me full particulars.

As there is no wood in the islands the fuel is either peat or coal, or, as I find very often to be the case, a mixture of the two. There are, however, certain districts in which absolutely nothing but peat is burned, and these show, as I expected, a death-rate below the average. In Stenness, for example, which has a cancer death-rate of only 1 out of 42 from all causes, peat is the universal fuel. The same is the case in Hoy, Rousay, Walls, Flotta, Orphir, and Stromness except in the town. Where only coal is burned, as in Papa Westray and Sanday, the proportion of cancer deaths to those from all causes is, as will be seen, 1 in every 9.

On the other hand, however, I was compelled to admit that in three districts at least there was a very high mortality from cancer in what appeared to be purely peat-burning districts. In Birsay, for example, cancer accounts for 1 death in every 8, and in St. Andrews for 1 death in 11, and both are almost entirely peat-burning districts. At first I thought that there must be some mistake, and that the patients must have burned some other fuel, but I was assured in several cases by the ministers of parishes, who kindly made the fullest inquiries, that cases had undoubtedly occurred in houses where nothing but peat had ever been burned.

In view of the Nairnshire results this seemed unaccountable, until it occurred to me that there might be peats and peats, and that the peat used in

Orkney might differ materially from that used in Nairnshire. Accordingly I got samples from the peat-stacks of various districts, and the result was a complete surprise.

These samples were unlike any peat which I had ever seen before. They handled like coal, were hard and stony in appearance, and, when portions were burned, crackled like coal and gave out long blue flames totally unlike the ordinary peat fuel, which simply smoulders and glows. On comparing one of these specimens of so-called peat with the Nairnshire, in colour the former was a dull black, while the latter was a warm brown, and bulk for bulk the Orkney peat was three times heavier than the Nairnshire.

If the ordinary characteristics were a surprise, the chemical analysis was even greater. I asked Dr. Drinkwater to analyse a sample for its sulphur contents, and his report was as follows:—

> "I must apologise for delay, but as the first analysis of the peat was extraordinary, I resolved to do it again myself, and my results confirm the first analysis. I find it contains 0·75 of sulphur, and approaches coal in character."

In view of this surprising result I decided to have a careful analysis made of the fuel burned in several districts which had a low or non-existent cancer mortality, and compare this with samples of Orkney peat. For this purpose I procured—

1. Peat from two bogs, Moss Side and Glenferness, in the Ardclach district of Nairnshire, in which district there had not been a single case of cancer in ten years among 1000 people.
2. A sample of peat from West Ross-shire, where I was assured by Dr. Pender Smith of Dingwall that after many years' experience he had never seen a case.
3. A sample from a moss near Fornighty, in Nairnshire, where the one case of rodent ulcer had occurred.
4. A sample from Nistaben, in the centre of Stenness parish in Orkney, which, as has been shown, has the very low mortality of 1 death out of every 42.
5. Three samples of peat from purely peat-burning districts in Orkney where cancer accounted for 1 death in 8 to 11 from all other causes.

The result of Dr. Drinkwater's analysis of these peats is very striking, and is as follows:—

	Total Sulphur per Cent.
Where cancer is practically unknown—	
Glenferness Moss, Nairnshire	0·101
Moss Side Moss, Nairnshire	0·189
West Coast of Ross-shire	0·120
Where it is rare—	
Nistaben, Orkney	0·237
North Verge of Ardclach, Nairnshire	0·238
Where it is very common—	
Sebay, Orkney	0·890
Red Loam Peat, Orkney	0·676
Tankerness, Orkney	0·750

The surprising result is shown, therefore, that although peat fuel is generally understood to contain practically no sulphur, some peat from the cancer districts in Orkney actually shows nearly 1 per cent. of sulphur, or in excess of the amount which is contained in many coals.

CHAPTER V

IS THE CONDITION CURABLE?

As matters are, to suggest that cancer is curable seems as fatuous as to suggest a method of perpetual motion, and yet it is unquestionable that cures have occurred, spontaneous or otherwise. The present hopeless attitude with regard to it is hardly to be wondered at, so long as its cause is considered an impenetrable mystery.

On the other hand, if it were realised to be parasitic in origin, this hopelessness would surely give place to hope, for a parasite such as I have referred to in my first chapter could be attacked in many ways.

In this connection I cannot help referring to the result of a discussion with the late Dr. Joseph Bell, but for whose sympathetic interest and encouragement I should never have presumed to pursue this subject so far. I had ventured to suggest to him that if cancer were parasitic in origin it should be affected by a heat of about 50° C., since the organism in order to flourish must have its optimum temperature. A great deal of work has been done in general biology in this direction, which shows that the germination temperature of parasitic fungi approximates naturally the temperature of the body of the host. Thus, those species which are in the habit of germinating in the digestive canal of warm-blooded animals have an optimum corresponding, as might be expected, with the temperature of the body of the animal. The normal temperature of different animals varies, which may account for the comparative immunity of certain animals.[1]

Although all such organisms have an optimum temperature, they have also a minimum and maximum. As a rule the minimum is very low, in some cases extreme cold having been borne without the power of germination having been in the least affected. On the other hand, the maximum temperature does not anything like so greatly exceed the optimum, and the very great majority of minute organisms akin to the fungi are destroyed by a temperature of about 50° C. It has been found, for example, that the organism which is the cause of actinomycosis has an optimum temperature of 32° to 37°, that growth is very slow at 38° C., and is arrested altogether at about 50°. A temperature of 70° for ten minutes has killed it altogether.

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[1] The normal temperature of the horse is 100·2, of the cow 101·4, and of the sheep 104.

Now, in view of these facts, if cancer is due to one of the mycetozoa, that organism should be destroyed by a temperature of 50° C. or 130° F.

My anxiety to test the effect of heat in this way was kindly met by Dr. Bell, who applied water at this temperature to a case of advanced epithelioma of the glans penis, with the extraordinary result that the primary sore entirely healed up, although, of course, the secondary growths, which made the case inoperable, were unaffected. Such a result seems to be fraught with great possibilities. It seems to me to prove not only that cancer is parasitic in origin, but that the parasite is of the class to which I have referred. If so, there ought to be an even more effectual remedy.

I have already stated in Chapter II. that lime has a most deterrent effect on *Plasmodiophora brassicæ*, that the disease never occurs on limestone or calcareous soils, and that the Board of Agriculture official leaflets state that it is unknown on soils containing even a high percentage of lime artificially placed therein. How the calcium acts is unknown, but if cancer be due to an organism of the same class as Plasmodiophora, it is reasonable to imagine that this might be affected by an excess of lime in the blood or tissues.[1]

Indeed, there seems to me to be the strongest indications that calcium *has* a deterrent, if not a curative, influence on cancer.

To begin with, we have the extraordinary fact that cancer is almost unknown among tanners and papermakers, who work daily with lime in large quantities.

Again, if we examine the facts in the few reported cases of actual cure of cancer, we find indications to the same effect.

One of the earliest of these is given in the *Lancet* of 12th October 1867, where there will be found a rather interesting letter by Dr. Peter Hood, of Portman Square, on the effect of oyster shells on a woman eighty years of age, who, he says, was cured of an enormous carcinoma by their use; and also on a man who had a tumour in his cheek as large as a small orange, and was cured by the same means. The shells were baked in a slow oven and the small white part picked out and powdered finely, as much as would lie on a shilling being taken once or twice a day in warm water or tea.

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[1] The discovery of the best known of all fungicides, Bordeaux mixture, is interesting. Its origin was this: As passers-by used to steal the grapes growing near the roadside, verdigris was spread on the vines, which people then considered poisonous. As verdigris proved expensive, the vine growers substituted a mixture of copper sulphate and *lime*. During the summer of 1882 the Bordeaux district was ravaged by the downy mildew in every vine except those treated with the mixture referred to. These, on the other hand, retained their leaves and gave an excellent yield of fruit.

If we can rely on these cases—and there seems no reason why we should not, when the letter is carefully read, it is obviously the lime in the oyster shells which was the curative agent.

But even taking later and scientifically reported cures, we find the probable influence of calcium, although this has been overlooked by the observers.

Perhaps the most striking of these is reported in the *British Medical Journal* of 1st July 1911, by Mr. Woods, President of the Royal College of Surgeons in Ireland. In this case of carcinoma of the larynx two operations had been performed, and a third had to be abandoned as the condition was found to be worse than appeared from external examination. Thyroid extract was then given as a last resource, when a complete disappearance of the growth ensued. Mr. Woods concludes his paper by asking why thyroid extract should have this effect in one or two cases and not in others. The recurrence which disappeared was in the lymphatic glands, but it is interesting to note that immediately after the first operation calcium iodide was given and after the twelfth day calcium chloride in order to stop the persistent bleeding, and that on the sixteenth day the granulations began to grow abundantly, and from this date the wound healed up.

In Beard's *Enzyme Treatment of Cancer* (1911) a striking case of an apparent cure by the use of trypsin and amylopsin is stated fully and illustrated by photographs. The credit is given to the enzymes used, but the fact that calcium was regularly used to increase the alkalinity of the blood must not be lost sight of. In my view the calcium was really the active agent.

As to violet leaves, it seems undoubted that one or two cures have been effected by their use.[1] So generally is this believed, that the wholesale chemists regularly prepare and sell refined infusions of these leaves, which are used daily. That these infusions have no effect is hardly to be wondered at, since in the cases of supposed cure, poultices or direct infusions of the leaves themselves have always been used.

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[1] *Viola Odorata.*—The flowers, leaves and entire plant of the sweet-scented violet have an ancient reputation in the treatment of cancer when taken internally and applied externally. The leaves of the Princess of Wales variety are said to give the best results in doses of 4 drams of a 1 in 1 liquor.

The wild pansy (*Viola tricolor*) is believed to have similar properties of checking the discharge and relieving the pain of malignant growths (Whitla's *Materia Medica*).

Now, if there be any virtue in violet leaves, we may fairly claim it again for calcium, from the amount which leaves contain. They are rich in calcium, and, as Pfeffer points out (*Plant Physiology*, vol. i. p. 585), "in those organs which are not used for storage the accumulated calcium remains for the most part permanently deposited. This is the case, for example, in foliage leaves, in which the absolute amount of calcium continually increases until the death of the leaf."

The salts of lime are present in very large amount in the tissues of animals, and considerable interest attaches to their absorption, excretion and general action. They form the great mass of inorganic constituents of the bones and teeth of the vertebrates and of the shells of the invertebrates. It has also been shown in recent years that they are present to a considerable amount in the soft tissues. Like other alkaline earths, however, calcium differs from the alkalies in possessing few soluble salts. Even the soluble salts penetrate with difficulty into the various tissues. They precipitate colloids such as the proteins in much more dilute solutions than the alkalies, and the precipitate is not redissolved by dilution with water.

The soluble lime salts are absorbed with great difficulty from the stomach and intestine. The great proportion of lime taken in the food unquestionably leaves the body entirely unabsorbed, while a small quantity is taken up from the alimentary canal whether administered in a soluble or insoluble form. This small quantity circulates in the blood probably in combination with proteins, and is slowly excreted unless there is a deficiency in the supply of lime, when it may be utilised by the tissues.

When larger quantities are thrown into the blood by intravenous or hypodermic injection the calcium contents remain abnormally high for some time, but all the calcium thus injected is not in the circulation throughout its stay in the body, some of it is temporarily deposited in some unknown organ, and is gradually withdrawn and excreted after the first excess is eliminated.[1] Soluble calcium salts injected directly into the blood-vessels have an action resembling that of digitalis. They also markedly contract the vessels. Large quantities injected intravenously contract the pupil to pin-point size, apparently from action on the sphincter muscle, as atropine has little effect. These effects are absent when the salts are taken up from the intestine, partly due to slow absorption, partly to the formation of albuminous compounds.

The action of calcium upon the fluidity of the blood is of course well known, and some of its other effects are curious, as, for example, the action of calcium lactate upon chilblains and the influence of lime water upon warts. It was lately stated in the *British Medical Journal* that a patient who suffered from warts, which no treatment would alleviate, was cured within a few days by drinking lime water.

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[1] Cushny, *Pharmacology*, 5th ed. 1910.

If, then, lime has such an effect upon warts, it is at least conceivable that it might have an effect upon malignant tumours.

The connection between calcium and certain enzymes thrombase, and particularly pectase, is very striking (see Reynolds Green's *Fermentation*, pp. 272 and 291). The action of pectase indeed depends entirely upon the reaction of the medium and the amount of calcium salt which it contains.

It should also be borne in mind that the parathyroid secretion in some way controls the calcium exchange of the body,[1] that the thyroid gland is said to be invariably atrophied in cancer cases,[2] and that the administration of thyroid extract has been followed by an amelioration of the condition.[3]

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[1] *Osler's System*, vii. p. 808.

[2] Bell, *N. Y. Med. Record*, 1907, p. 260.

[3] Stiles, *Ency. Medica*, vii. pp. 337, 338.

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